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ABSTRACT

This study investigated the development of effective large-group instructional materials which are relevant and meaningful to the general studies biology student. The criterion of student interest guided the selection of birth, birth control, and genetic counseling as topics for developing relevant prototype instructional materials. These materials utilized many types of instructional methods, including audio-tutorial, programmed instruction, film clips, case histories, and the Didactor computer-type teaching instrument. A pilot study of the prototype materials was conducted with six volunteer students. After being introduced into the regular general studies biology format, analysis of student feedback, questionnaire appraisal, and comprehensive testing of over 600 students led to the final revision of instructional strategies. Questionnaire appraisal of the finalized prototype instructional systems indicated that a decisive majority of students reported the instructional systems to be relevant, current, and interesting. Test data analysis indicated that the students achieved beyond the minimum established criteria for the success of the prototype instructional systems. Test data indicated that the selection of instructional strategies were effective means for the attainment of the respective student behavioral objectives. (Author/MH)

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A SYSTEMS APPROACH WITH DIDACTOR-ASSISTED INSTRUCTION APPLIED TO THE COGNITIVE DOMAIN IN BIOLOGY

A DISSERTATION

SUBMITTED TO THE GRADUATE EDUCATIONAL POLICIES COUNCIL

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

for the degree

DOCTOR OF EDUCATION

by

DANIEL J. DYMAN

BALL STATE UNIVERSITY

MUNCIE, INDIANA

JULY, 1972

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A Systems Approach with Didactor-Assisted Instruction
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Daniel J. Dyman
Ed.D.
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The demand for relevance and attention to teaching strategies are among today's critical issues in higher education. Subject matter should be related to the practical and intellectual concerns of the student and technological aids for individualized instruction should be more fully explored.

Accepting these premises for the improvement of education presents the problems: (1) developing instructional materials with content areas organized to include relevant topics; (2) designing a systems approach to individualized instruction which incorporates expedient technological resources; and (3) testing the instructional materials to determine if preconceived objectives were achieved. In addition to the basic problems, this study involved the implementation of the Didactor, a computer-type teaching instrument, to assist the instructional endeavor and aid the student in the learning process.

The general studies biology course at Ball State University was selected as an ideal setting for conducting this research because the course accommodates large numbers of students with an array of background and interest characteristics.

The criterion, student interest, guided the selection of Birth, Birth Control, and Genetic Counseling as topics for developing relevant

prototype instructional materials. Student behavioral objectives were formulated and instructional systems were built upon strategies which attempted to select the most appropriate teaching media to attain the designated outcomes.

Audio-tutorial instruction was the basic mode into which systems for individualized instruction and technological resources were implemented. Programmed instruction was utilized to treat involved concepts such as the effects of the "Pill" on the menstrual cycle. Experiments such as the influence of drugs on chick embryo circulation were designed to involve students in guided discovery. Directed observations of a variety of specially designed visuals including a film clip of vertebrate sexual reproduction, a working model of fetal osmosis, and a 35 mm slide series on removing chick embryos were implemented to teach facts, concepts, principles, and techniques. Readings of case histories such as "What Doctors Now Know About Your Unborn Baby" were incorporated to stimulate interest. A Learning Guide was designed to direct student interactions with the instructional system, recording observations and responding to problem situation. And, Didactor programs were developed according to a branched format to contribute an additional dimension to the learning environment, monitoring the student's learning progress and providing corrective information as needed. The Didactor programs were designed to treat complex subject areas such as neurulation, menstrual cycle, and inheritance.

A pilot study of the prototype materials was conducted with six volunteer students. Test results and feedback from the pilot study group were analyzed and where necessary, new strategies were

incorporated to enhance the effectiveness of the instructional system. After being introduced into the regular general studies biology format, analysis of student feedback, questionnaire appraisal, and comprehensive testing of over 600 students led to the final revision of instructional strategies.

Questionnaire appraisal of the finalized prototype instructional systems indicated that a decisive majority of students reported the instructional systems to be relevant, current, and interesting. Test data analysis indicated that the students achieved beyond the minimum established criteria for the success of the prototype instructional systems. Furthermore, test data indicated that the selection of instructional strategies were effective means for the attainment of the respective student behavioral objectives. Lastly, the Didactor was found to be a significant instrument in facilitating learning at the knowledge, comprehension, and application cognitive levels.

The study has provided a basis for the development of effective large group instructional materials which are relevant and meaningful to the general studies biology student and a starting point for research whereby each component in the instructional strategies can be tested for its particular contribution to the instructional system.

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CHAPTER I

PROBLEM

Introduction to the Problem

The significant factors which are influencing educational introspection can be categorized as: (1) student concerns; (2) pedagogy; and (3) learning principles. Among the student concerns are a demand for relevance and an accumulation of knowledge at an accelerated rate. Teaching methodology should involve the implementation of self-instructional systems which utilize technological resources and the application of teaching skills. Reinforcement, student activity, problem solving, discovery, and internalization are integral elements of existing learning theory.

If the educator is to consider fully all of the constituents which affect the educational process, the instructional plan must incorporate selectivity of subject matter (Haney and Ullmer, 1970). With the first microteaching clinic at Stanford University in 1963, Allen and others stimulated interest in the application of technical teaching skills to improve the instructional process (Allen, 1967). Research has shown that the use of basic teaching skills can produce intended student behaviors. Banister (1970) has encouraged the renovation of the teaching-learning endeavor by taking advantage of available technology. Technology must become more than just an aid to the instructional process. It must become an integral part of the instructional system.

The learning theory proposed by Skinner implies student

participation and requires the application of reinforcement (Skinner, 1954). Applications of the reinforcement theory of learning in the form of programmed instructional materials can be effective in facilitating the learning of basic factual information and manipulative skills (Haney and Ullmer, 1970). However, the achievement of higher order mental activities, such as internalization, problem solving and discovery, is of more consequence to educators. According to Piaget as reported by Jennings (1967), understanding can be achieved only through discovery, "anything is only understood to the extent that it is reinvented." Bruner's conclusion is that, "Instruction consists of leading the learner through a sequence of statements and restatements of a problem or body of knowledge that increase the learner's ability to grasp, transform, and transfer what he is learning" (Bruner, 1967).

Statement of the Problem and Purposes of the Study

The problem of this study involves the application of the systems approach to three major educational areas. The first problem aspect involves the development of instructional materials which, founded upon basic biological principles, are relevant and have utility to the student. As one purpose of this study, instructional materials were written for the areas of Birth, Birth Control, and Genetic Counseling. The topics of the instructional materials: (1) Birth, focused on animal development and some factors affecting the developmental process; (2) Birth Control, concerned contraceptive methods, some causes of congenital defects, and reproductive patterns of some organisms; and (3) Genetic Counseling, concentrated on the principles of inheritance and the application of those principles to human heredity.

The second parameter of the problem includes the design of learning strategies for individualized instruction which utilize available media and technological resources. As a second purpose of this study, learning strategies were developed to center upon the audio-tutorial mode of instruction, incorporate a student Learning Guide, and utilize a variety of visuals.

The third issue of the problem comprises the evaluation of the instructional materials and strategies to determine achievement of the student, effectiveness of the materials and strategies, and student regard in terms of relevance, practical value, and interest. As a third purpose of the study, achievement tests and questionnaire appraisals were constructed. The test data that was generated through the use of the evaluation instruments was statistically treated using the analysis of covariance for pretest and post test groups. The questionnaire responses were compiled and mathematically expressed in percentages.

In addition to the basic problem, the teaching effectiveness of the Didactor which is intended to supplement the instructional materials was determined. The Didactor is a computer-type teaching machine capable of accommodating intrinsic, branched, program materials. Didactor programs treating some of the completed instructional materials in Birth, Birth Control, and Genetic Counseling were written. The programs were used by students as a component of their self-instruction. The teaching effectiveness of the Didactor programs was determined using the achievement tests that were developed to assess the effectiveness of the instructional materials and strategies for Birth, Birth Control, and Genetic Counseling. Analysis of covariance was the statistic used to compare the achievement of control and Didactor groups. A questionnaire appraisal instrument was

developed to determine student opinion about the value of the Didactor and Didactor programs as teaching aids. Questionnaire data was tabulated and expressed in percentages.

The Significance of the Problem

One goal of educators is to strategically structure learning experiences which lead students from that which is within their grasp to higher levels of understanding and behavior (Bruner, 1961; Novak, 1965). In formulating learning strategies, goals must be identified in terms of performance criteria; students should be able to achieve the goals as indicated by their responses to evaluative instruments; and, a variety of strategies and media should be implemented for learning endeavors (Banister, 1970; Briggs, 1970; Dean, 1971). Furthermore, significant factors in education, relevance (Smith, 1970; Morris, 1970), and the increasing rate at which new knowledge is accumulating, are coercing educators to be selective in choosing course content (Haney and Ullmer, 1970).

The results of this study can serve as a model for the continued improvement of the education process, for the pre-service training of college teachers, and for in-service programs in college teaching.

CHAPTER II

REVIEW OF RELATED LITERATURE

Factors developing over the last twenty-five years from three distinct sources, learning theorists, media specialists and military budget programs, have notably influenced the concern for educational improvement and accountability. Ausubel (1968, 1963), Bruner (1967, 1963), and Gagne (1970) have provided much of the theoretical background for instructional improvement. The increased use of the self-instructional mode initiated by Postlethwait (Postlethwait, Novak, and Murray, 1969) supplying the impetus for the implementation of multimedia facilities also has affected educational improvement. Finally, the origins of educational systems accountability are rooted in United States Department of Defense budget programs (Tanner, 1969).

Theoretical Background

A main focus of Ausubel's learning theory is "reception learning" which is concerned with "the psychology of how individuals comprehend, learn, organize, and remember large volumes of meaningful verbal materials" that they typically encounter in a classroom situation (Ausubel, 1963). According to Ausubel (1963), reception learning, not to be confused with rote learning, is derived from the instructional process of subject matter presentation rather than the process of discovery.

To have meaningful reception learning requires the process of "subsumption" which involves both interaction and inclusion of new knowledge with previously acquired information. Thus, with acquisition, knowledge is subsumed into more inclusive concepts resulting in higher

levels of comprehension (Ausubel, 1968, 1963). The efforts of Novak and several of his students (Ring and Novak, 1971; Thorsland and Novak, 1972; Hubbard and Novak, 1972) have supported the Ausubelian subsumption theory.

In addition to subsumption, Ausubel's learning theory involves the constructs of "expository organizers," "comparative organizers," and "anchorage". Expository organizers, provided prior to instructional presentation, prepares the learner's cognitive structure for the reception of new knowledge; comparative organizers are used to integrate existing concepts with similar concepts which remain to be learned; and anchorage involves the addition of new information to existing concepts which serve as nuclei or anchors (Ausubel, 1968, 1963). The technical teaching skills, "establishing set" and "establishing appropriate frames of reference," identified by Allen (1967) appear to be classroom accommodations of Ausubel's theoretical anchor and organizers.

Because subject matter presentation is the most conventional instructional mode, reception learning is the most typical form of knowledge acquisition. Thus, to substantially improve the educational process, emphasis should be placed upon improving the methodology of subject matter presentation (Ausubel, 1968, 1963). According to Ausubel (1968, 1963), students must be prepared for the instructional process, and by proper sequencing of instructional materials, new knowledge may be efficiently added to their cognitive structure. To be meaningful, a curriculum must be concerned with the systematic presentation of its subject matter (Ausubel, 1965).

The principle underlying Bruner's theories of instruction and processes for education is "that any subject can be taught to any child

in some honest form" (1963). However, the challenge facing the instructional process is to properly devise learning sequences which facilitate the educational process (Bruner, 1965). Since the mind can effectively deal with only a few operations at a single time, disorganized information will probably effect learner frustration and confusion (Bruner, 1961).

A series of episodes involving acquisition, transformation, and evaluation are usually required if learning is to occur. Acquisition of new information occurs as an alteration or replacement of what has been known; transformation is the process of manipulating new knowledge to make it fit new tasks; and evaluation is checking the adequacy of the transformed acquisition (Bruner, 1963).

Central to the instructional process should be the provision of appropriate aids and dialogues for the establishment of more effective conceptual hierarchies. The instructional process should be concerned with the formulation of environments which optimize learning (Bruner, 1967).

Gagne (1970) defines learning as "a change in human disposition or capability, which can be retained, and which is not simply ascribable to the process of growth". Learning is more than just a natural phenomenon that happens as a result of development. It is to a large extent dependent upon events in the environment. And, it is an event that occurs under precise conditions which can be objectively described. In essence, learning is an event which takes place when a stimulus, applied to the learner, results in a detectable performance change. The learning which does occur is inferred by comparing performance before and after student involvement within the learning environment.

Gagne's observations of learning situations and performance outcomes resulted in the identification of eight kinds of learning ranging from "signal learning," the least complex, to "problem solving," requiring complex internal events. The various classes of learning suggest a learning hierarchy. Each learning type has its own characteristic environmental conditions which effect precise detectable performance changes. To bring about effective and efficient learning, good instruction should be carefully organized to provide the conditions which are required for the achievement of a particular learning level. Good instruction is planned to provide for the specific conditions applicable to the task being learned, learner capabilities, learning preprequisites, and learning structure (Gagne, 1970).

The Application of Technology

Technological applications to education date back to the mid 1800's (Stolurow and Davis, 1965). According to Stolurow and Davis (1965), teaching machines were developed and patented as early as 1866. In 1926, Pressey (1926) proclaimed the educational value and feasibility of teaching machines. However, Pressey's recommendation remained unheeded because, as Skinner (1958) pointed out, the "industrial revolution in education" which was predicted "stubbornly refused to come about."

The technological applications to education which finally began to evolve in the 1960's received momentum from the varieties of audio-visual aids and the emerging science of learning (Glaser, 1960). The vast array of media available to the educator offers him powerful and flexible communication tools which have affected his role and the quality of learning

experiences for his students (Haney and Ullmer, 1970). According to Haney and Ullmer (1970) research in audio-visual communication generally has reported significant learning gains attributable to media. In recent years, teaching machines and other related self-instruction instruments have attracted widespread attention with much of the attention focused upon the nature of the specific device as a means for instructional presentation (Lumsdaine and Glaser, 1960). Bunderson and Butts (1969) caution educators to be "concerned about the accuracy of any media and to not succumb to the attractive appearance alone." As aptly said by Dean (1971), "we can prevent the media from becoming the message if the program is student oriented."

Concurrent with the widespread implementation of audio-visual communication devices, renewed interest in teaching machines, and advancements in the science of learning, Postlethwait et al., (1969) unaware of the impact, introduced the audio-tutorial approach to learning. Audio-tutorial instruction began as an attempt to ameliorate learner differences in general botany by inviting the students to listen to special audio tapes. After the first semester of implementation at Purdue University, Postlethwait et al. (1969) observed that a "lecturer in person" was necessary for adequate learning and that the subject matter of the lecture and laboratory could be correlated on an audio tape.

The success of the audio-tutorial approach to instruction was immediately apparent and quickly developed into a common instructional mode. As the audio-tutorial mode of instruction became more widespread, it began to act as a medium for multimedia communication (Haney and Ullmer, 1970), a setting for the application of learning theory

(Siemankowski, 1971), an environment for educational innovation (Hoffman and Druger, 1971), and a carrier for the utilization of teaching machines (Herrick, 1969a, 1969b).

According to Haney and Ullmer (1970), audio-tutorial instruction is "an excellent technique for involving learners in a variety of participating experiences all the way from taking notes or filling in blanks to performing some experiment." In recent years, media have become synonymous with systems of learning that extend throughout a course (Henich, 1966). A common mix of media in a system includes books, programmed materials, workbooks, simulations, illustrations, photos, filmstrips, motion pictures, video tapes, records and audio tapes (Frueling, 1971; Branson, 1971; Briggs, 1970). In application, the array of media is systematized into a structured format known as multimedia approach. According to Geisinger (1968), combinations of media should be used in a learning situation to accommodate individual differences whereby one medium may be used to stimulate motivation while another medium may be implemented as a means in the presentation of special information. Banister (1970) defines multimedia as a "preplanned system of instruction using many means ranging through lectures, discussions, field trips, experiments and other teaching and learning activities." Briggs (1970) considers multimedia to be a deliberately chosen selection of media intended to effect a particular instructional strategy. Several innovative and meaningful case studies using the multimedia approach have been reported by Banister (1970) to have had a positive learning effect.

Siemankowski (1971) applied the Skinnerian reinforcement theory in the design of the audio-tutorial format by periodically requiring a written student response. Following the response the principle of

reinforcement was applied by giving the correct answer and indicating why it was correct. Results of this application of learning theory resulted in significant learner gains.

Hoffman and Druger (1971) have enhanced the educational capability of the audio-tutorial format by adapting the Amidon-Flanders interaction analysis to the design of audio tapes. As a result of adjusting the audio tape format to include student activity sequences, significant gains were achieved in student problem-solving ability and attitudes (Hoffman and Druger, 1971).

Herrick (1969a, 1969b) have expanded the audio-tutorial approach at the School of Medicine, University of Missouri-Columbia, to include the Didactor. Regardless of the format, programmed instruction is presented to the learner through a device known as a teaching machine. Although various machines can be utilized to present linear and branched programmed learning materials, books generally characterize linear formats and computers generally typify branched orientations (Didactics Corporation,a). Because branched programmed learning materials readily provide for in-depth thinking and problem-solving, they are most useful; but computer costs seriously limit their economic practicallity. However, with the advent of the Didactor (Figure 1), a device which "provides a practical approach to computer assisted individualized instruction" (Didactics Corporation,b) branched programmed learning materials can be liberally implemented (Herrick, 1969b). In common with other teaching machines, the Didactor presents information in small steps, offers an opportunity for frequent student responses, gives immediate feedback, and permits progress adjusted to need and ability. According to Herrick (1969a, 1969b) the teaching potential of this computer-type machine has

FIGURE 1. The Didactor in use. Located at the left are student response buttons; on the right are program indexing and timer controls; and in the center is the 4" x 6" screen for viewing the program frames.

a high level of sophistication and shifts the instructional emphasis to the student by monitoring his progress and compensating for his errors. Furthermore, the Didactor is more than just an "automated page turner . . .The device is totally flexible leaving all programming decisions to the instructional programmer" (Herrick, 1969a).

Flexibility in the program presentation of the Didactor is exceptional (Herrick, 1969a). Unsprocketed 35 mm photographic film contains the programmed learning materials to be viewed by the learner placed side by side with the coded information which directs the Didactor's operative mechanism. As many as 300 frames of coded learning material can be incorporated on a Didactor filmstrip and each frame can provide a maximum of five multiple choice responses (Didactics Corporation,b).

Because of the unique qualities of the Didactor, a programmed filmstrip can be presented to the student in a branched design. Since each student is directed through the program according to his own responses, few students will ever proceed through a given program in exactly the same way. A student who learns rapidly will tend to follow the mainstream of the program. A student who experiences difficulty, will generally be detoured to the specific corrective, remedial, or supplementary material. If complete mastery of a sequence of frames is required, a Didactor memory system which "watches" the student's performance will automatically repeat the set of frames according to need. A Didactor timing device can be used to quicken the pace of learning and encourage attentativeness and concentration. For students unable to complete a program in one sitting, the Didactor indexing system allows the student to interrupt his study and return without losing his place

in the program. In addition, the Didactor can be modified to accept and control a sound-mate system (tape recorder) or a slide-mate system (carousel-type slide projector) or both (Didactics Corporation,b).

Gradually, the focus of audio-tutorial instruction is shifting to the development of self-contained instructional modules which are directed to the achievement of a restricted number of well defined objectives (Murray, 1971). The present concern of many programmers of audio-tutorial instruction is for the development of minicourses of instruction which provide the learner with an integrated sequence of learning experiences oriented toward individual performance (Postlethwait and Russell, 1971). According to Postlethwait and Russell (1971), minicourses provide several worthwhile qualities such as (1) flexibility for differences in entering competencies among learners; (2) accommodation for mastery learning; and (3) versatility for developing learning strategies suited to the accomplishment of specific objectives.

Basis for Systems Accountability

A call for a systematic learning theory was made by Skemp (1962). According to Skemp (1962),

> A theory is required which takes account (among other things) of the systematic development of an organized body of knowledge, which not only integrates what has been learnt, but is a major factor in new learning: as when a knowledge of arithmetic makes possible the learning of algebra, and when this knowledge of algebra is subsequently used for the understanding of analytical geometry.

Novak (1970) stated

> As a profession, we educators stand today in a category analogous to the nineteenth-century farmer; we learn from one another how to teach, but little of our practice is founded on basic research.

There is no evidence to suggest a connection between the Skemp's recommendation of systematic instruction and the application of system accountability to education but for educators, the way was being prepared for the systematic structuring and analysis of the instructional process.

The seed for the instructional system accountability was sown with the British attempt to maximize the World War II operational effect by the utilization of every available resource. The program which evolved from the British effort was known as "Operations Research" and involved the application of an interdisciplinary team of specialists and the scientific method to select means that best served the organized effort (Ackoff, Gupta, and Minas, 1962; Allen, 1967; Tanner, 1969). Later, the United States Department of Defense adapted the British Operations Research program in the development of the Polaris missile system (Tanner, 1969). The best known of the economic tools to evolve from the Polaris project was Program Evaluation and Review Technique, PERT (Anderton, 1969; Tanner, 1969). According to Haga (1965),

> PERT . . . is a powerful management tool for project schedule monitoring and control. The basic element is a work flow network defining sequential relationships and dependencies of each of the steps, or mile

Garlock (1968) has defined PERT as

> a set of principles, methods, and techniques for planning programs in relation to objectives, interrelating and controlling variables of time and resources, scheduling events and activities, and replanning research or development programs.

In essence, PERT is a technique which provides a diagrammatic interconnection of a complete program system (Garlock, 1968). The application of PERT in the development of weapon systems gradually filtered from the Department of Defense into other government agencies, industry, and finally education (Tanner, 1969).

Applied to education, PERT is a tool which can be utilized by the educator to develop a package of instructional material and keep the material in a continuous process of assessment and modification. Also, PERT provides the means for allocating resources to activities in an attempt to maximize their effectiveness (Kaufman, 1971; Tanner, 1969).

Other economic tools which have evolved from "Operations Research" are Critical Path Method, CPM, and Programming Planning Budgeting Systems, PPBS (Kaufman, 1971). Kaufman (1971) indicates that CPM, like PERT, was introduced to enable educators to effectively manage and control educational implementation. However, the basic difference between CPM and PERT is that CPM considers the concept of cost in the planning and the control processes (Levin and Kirkpatrick, 1966).

The purpose of PPBS is to help the system accomplish its objective in the most efficient and effective manner (Gibbs, 1968) with emphasis being placed upon both achieving program objectives and cost effectiveness of the program (Wooton, 1971; Kaufman, 1971). In application criteria whereby objective achievement can be determined (Rath, 1968). According to Rath (1968), a necessary input is the generation of imaginative and good alternatives which permit the assembly of various combinations capable of being evaluated.

The most ambitious educational analysis project was undertaken in 1967 by a group of specialists representing government, education, community, and industry. The meeting was convened to encourage the communication of ideas, developments, and techniques which could contribute to the advancement of quality and efficiency in the nation's education

and training program (Lehmann, 1968). As the project developed, it adopted the name of Annual Review and Information Symposium on the Technology of Training, Learning and Education or Project ARISTOTLE (Geisinger, 1968;Lehmann, 1968). The outcome of the symposium was the establishment of an eight step systems program for the analysis of the instructional process. According to Geisinger (1968), the eight steps presented by the committee are: (1) statement of a need, the problem; (2) identification of objectives, measurable learning goals; (3) determination of constraints required to guide the selection of alternatives; (4) establishment of alternatives, generally a list of potential solutions; (5) selection of the most feasible alternative; (6) implementation of the selected alternative; (7) evaluation of the selected alternative; and (8) modification, an iterative process tending toward perfection.

Meals (1967) predicted that system analysis applied to the process of education is not a passing fancy; it has been proven to be effective in both the military and technical community. System studies offer the potential to "trace out and assess the impact of a new policy on related activities in order to predict how effective the total set of interacting elements (a system) will be on performing its mission" (Meals, 1967). Lave and Kyle (1968) consider systems analysis to be a method to guide practical decision making. For Gibson (1968) systems analysis is "a combination of men and machines which make maximum use of all resources, whether they be human or mechanical in nature. According to Gibson (1968), systems analysis can be used effectively to gain educational dividends. In agreement with Gibson, Mauch (1962) considers the aim of systems analysis to be an approach to find the most efficient and

economical methods to accomplish educational tasks. Cyrs and Lowenthal (1970) point out that system analysis attempts to increase the effectiveness of education by designing instructional processes to ensure student achievement of its objectives. Applied to education, systems analysis is concerned with the entire instructional system including the media used, the content, and the best combination of media and content to effect learning (Meals, 1967). As McLaughlin and Hobbs (1970) view the application of systems analysis to education, it is "an attempt to do a better teaching job by defining the desired educational or behavioral outcomes and then designing the entire process to assure appropriate student achievement." Lastly, Horton (1963) proposed the use of systems analysis to coordinate all controllable stimulus sources that can reach the student. Horton (1963) continues, "If this application of systems analysis to education could be done, we might find that coordinated application of all stimuli has greater effects than the sum of separate effects and piecemeal application."

The application of the systems analysis approach to education has found several meanings (Silvern, 1968). According to Brayman (1966), the systems approach involves the assembly of "components and fragments of learning equipment from a multitude of sources . . . into an integrated capability." Cyrs and Lowenthal (1970) view the systems approach as a process incorporating the students, teachers, curriculum content, instructional materials, instructional strategy, physical environment, and the evaluation of objectives. Silvern (1968) considers the systems approach to be an "orderly whole" which he hopes will include with it "part of the real life environment for which the learners are being prepared and from which feedback may be obtained to cause the curriculum

parts of the system to be modified to keep up with, or even ahead of, the needs of the real-life environment."

Though the definitions of the systems approach may literally vary, in application, the systems approach tends to involve basic phases or fundamental steps. In the plan offered by Albracht (1971), the systems approach involves three major dimensions, student, teacher, and instructional material. The student must be considered in terms of learning styles and the things he needs to know. The teacher is the most important element of the instructional design because, the teacher must have teaching and technological competence, make sure the units are relevant to individual needs, select the best available methods and media to develop the student abilities. The instructional material should be economically considered in terms of time and cost requirements.

Henich (1966) considers the instructional system to consist of three parts: curriculum determination, deciding what is to be learned; strategy planning, involving methodological decisions and instructional assignments; and implementation, executing the instructional program. According to Barson (1966) the systems approach in education must include the identification of course objectives, determination of strategy, selection of media, and perception of the requirements of implementation.

Weins (1966) at Oakland Community College developed a "Learner-Centered" instructional systems approach which involved five steps, stating objectives in behavioral terms, organizing sequences of media, orienting the learner with a study guide, involving the learner in a self-paced program, and evaluating criterion responses. Banister (1970) suggests the use of an eight step systems approach design which includes

developing terminal behavioral objectives, selecting content, sequencing learning events, determining a mix and balance of media, deciding on the media for each learning event, establishing a schedule for the system, designing learning events, and designing an evaluation and reward system. Cyrs and Lowenthal (1970) recommend a ten step systems design which includes the unique features of pretext diagnosis of the population for whom the instructional materials are designed, development of original materials when necessary rather than commercial materials which may be less appropriate to the learning requirement, and on going evaluation and revision relying upon pilot study groups, interviews with students, attitude surveys and questionnaire appraisals. Lastly, Bunderson and Butts (1969) propose one of the most thorough and comprehensive instructional system design which includes (1) needs and justification involving program goals, descriptions of the student population, institutional constraints, and justification of the approach; (2) instructional design, providing for goal synthesis, task and learner analysis, synthesis of the instruction system, and production of materials; (3) evaluation and revision, requiring editorial and empirical evaluation; and (4) use of feedback, assuring an evaluation-revision cycle. Several advocates of the systems approach recommend a needs analysis as the initial step in the development of an instructional program. As reported by Briggs (1970) there is little value in improving the instructional process if what is being taught "turns the student off."

> Thus, the broadest, most effective, and most humane applications of a 'systems approach' should take into consideration the learner's needs and wishes in a systematic search for meaningful objectives, and appropriate measures for achieving them. The learner represents a key component in the system, and should be considered in applying the systems approach to educational planning.

As Kaufman (1968) indicates, "In education, we are attempting to meet needs: needs of society, needs of learners, and needs of educators to be responsive to requirements placed upon us by those we strive to serve." According to Kaufman (1968) "A need is . . . the discrepancy between what is and what is required." Furthermore, needs are only identified through a process called needs assessment which includes the recognition of relative discrepancies. The result of needs assessment provides an increased probability for developing a curriculum of relevant content.

According to Bruner (1965), it is essential to have a "clear sense of what has to be attained at later stages to plan the order of learning at earlier stages." Kaufman (1971) recommends that a needs assessment be empirically prepared. Cyrs and Lowenthal (1970) recommend that a needs assessment also include a pretest diagnosis of the typical learner population to empirically determine the learning requirements of the "proper learning packet." The needs assessment established by Branson (1971) for the design of a systems approach physics course was based upon the examination of four widely used textbooks. In addition to the establishment of course content as a rationale for needs assessment, Koskey (1971) recommends that the interests of the learner be kept in mind and Dean (1971) advises that the analysis of student needs include the dimension of societal needs. Similarly, Albracht (1971) indicates that careful consideration be given to both the cultural and societal needs of the student. According to Combs (1965),

> Students must be given a voice in matters that concern them and opportunities to consider and plan for further experiences. A program built around student needs which does not involve students in the business of planning seems an anomaly indeed.

Based upon the needs assessment, behavioral objectives should be written. According to Dean (1971), each behavioral objective should be linked to a concept or attitude which has been identified in the needs analysis. The behavioral objectives should be clear and concise including the: (1) learning task to be accomplished; (2) conditions under which the task is to be accomplished; and (3) criteria under which the learning task is to be accomplished (Park, 1972; Kaufman, 1971; Mager, 1962). Depending upon the learning task, the objectives may be related to cognitive, affective, and/or psychomotor goals (Dean, 1971). In some instances, the behavioral objectives should be analyzed and separated into a hierarchy of intermediate objectives which indicate the sequence of learning goals which must be accomplished to achieve higher order objectives (Bunderson and Butts, 1969).

"Specifying learning objectives is a teaching method which is highly effective in promoting basic educational goals" (Park, 1972). According to Park (1972), learning objectives are mutually acknowleged by both teacher and student--eliminating all speculation about the desired end, as well as the conditions of measurement and the criterion required." Cyrs and Lowenthal (1970) advocate use of behavioral objectives for the benefit of both the student and teacher because the objective indicates exactly what is expected with the completion of the instructional system and it provides the student with assurance that evaluation will reflect his skills, knowledge, and concepts. Furthermore, Cyrs and Lowenthal (1970) consider behavioral objectives to be essential to the selection of instructional material and the development of teaching strategies which assure the achievement of the stated objectives. Similarly, Haney and Ullmer (1970) suggest the use of behavioral objectives for (1)

communicating with the students; (2) constructing test items, and (3) selecting media, materials, and methods. From a vast array of content, the teacher "must select objectives that are worthwhile . . . decide how learner competencies will be judged . . . and structure sequences of learning events that will be effective in bringing about these competencies" (Haney and Ullmer, 1970). Thus, learning objectives have a threefold role in the instructional process: (1) objectives are effective in directing the learner; (2) objectives are essential in the selection of instructional processes and methods; and (3) objectives provide a sound basis for evaluation.

In their instructional system sequences, Cyrs and Lowenthal (1970), Briggs (1970), and Geisinger (1968) include pretest analysis of identified behavioral objectives. Anaylsis of pretests can serve as a guide in media use and strategy development because pretest data can aid in the identification of instructional conditions which are optimal to learning particular kinds of behavioral tasks and/or activities which are related to the subject matter (Glaser, 1966). Glaser (1966) indicates that pre-instructional behavior analysis should help in the determination of the beginning point for guiding behavior through teaching. Frueling (1971) considers pretest data helpful in planning media that can best lead the learner from the level of entering competency to a level of intended competency. According to Briggs (1970), results of pretesting may identify objectives which can be eliminated because the target population has demonstrated satisfactory competency. Beside guiding instructional strategy and influencing media selection, pretest data can provide a measure of existing cognitive structure (Ring and Novak, 1971) which can

serve as a basis for determining net learning gain (Allan, Lagowski, and Muller, 1970; Diamond, Regelski, and Lehr, 1971). Screven (1967) has even found pretesting improves learning by helping the learner identify the concepts that are to be learned.

With the framework of content, statement of objectives, and description of the student instructional state, the instructional process can be carried out (Glaser, 1966). Because a particular instructional system may intend to optimize student performance, that is, transfer and/or cost; and another may focus on testing a new curriculum; an "optimization rule" of teaching strategies should be applied and a number of alternative strategies should be selected (Belgard, 1971).

Rarely in education is a single solution to a problem sufficient (Carpenter, 1971). According to Carpenter (1971) a single solution does not (1) indicate whether the decision maker could be doing better; (2) offer opportunity to exercise judgment; nor (3) provide the likelihood of discovering new features. Thus, the analysis of strategy alternatives involving the description of resource requirements, effectiveness, and the process relationship between resource requirements and effectiveness is required (Carpenter, 1971). "Everything that is said in class or assigned for the student to do must be for the purpose of assisting him in achieving a learning objective or a set of objectives" (Elkins, 1970). Similarly, Novak (1964, 1965) and the National Science Teachers Association (1964) recommend that curriculum materials and instructional involvements be designed and sequenced to lead students to an acquisition of information and the understanding of basic conceptual schemes.

Glaser (1966) offers some general considerations and guidelines in the development of instructional strategies which include (1) the

examination of the conditions of instruction such as sequencing, stimulus-response factors, and amounts of practice and review; (2) the need for maintaining motivation; and (3) the provision for assessment and evaluation. According to Koskey (1971), five operations are significant in the design of an instructional system. The operations are: (1) searching for relevant available materials; (2) producing materials which are not commercially available; (3) organizing materials into a unit; (4) sequencing the units into a logical pedalogical flow; and (5) creating a relevant student evaluation system.

The principal task involved in developing instructional strategies is relating the best combination of media and methods (Haney and Ullmer, 1970; Briggs, 1970) but little empirical data exists which identifies the best combination (Bunderson and Butts, 1969; Haney and Ullmer, 1970). In practice, reliance must be placed upon a consideration of learner variables and task variables when making decisions about instructional strategies and media selection (Briggs, 1970). When planning the learning experiences, Borg (1969) suggests a practical approach relying upon (1) the use of judgment and whatever evidence is available to identify and define what the learning experience is to involve and (2) develop and test the instructional model gathering evidence which, not initially available, can aid in the incorporation of needed changes. To aid in the gathering of evidence which relates the effectiveness of strategies, the various steps in the instructional program should be documented with notes about the purpose and intended strategy (Dean, 1971; Bunderson and Butts, 1969).

In selecting an instructional strategy, the method of inquiry should be emphasized because this strategy enables the student to engage

in problem solving that can carry over after the instructional period (Dean, 1971). According to Dean (1971), the inquiry instructional mode will indicate to the student that learning involves discovery, exploration, experimentation, questioning and debate. Finally, Dean (1971) recommends that the instructional sequence should include opportunities for observation, reflection, and problem solving which enhance motivation, conceptualization, and generalization.

The selection of media should include a consideration of the media characteristics and the type of instructional task for which it is most appropriate (Haney and Ullmer, 1970).

Banister (1970) suggests films, slide shows, guest speakers, panels, and social dramas for large group interaction; discussion, reports, task group work, and quizzes as small group media; and video tapes, audio tapes, illustrations, filmstrips and film loops for individualized instruction.

Several research studies have been made to determine the relative effectiveness of some instructional media compared with some forms of traditional instruction (Haney and Ullmer, 1970). According to Haney and Ullmer (1970) most of the studies do provide data which tends to "support the general intuitive feeling that people do indeed learn well from the use of media."

Dyman and Nisbet (1972) have reported that directed observations of sketches, photos, models, preserved and living specimens, simulations, and filmclips are effective media at the cognitive levels of knowledge, comprehension, and application. In addition, Dyman and Nisbet (1972) indicated that programmed instruction is an effective medium for knowledge and comprehension learning, selected readings are meaningful for application learning, and 35 mm slides are useful for psychomotor skill learning.

Following the development of the instructional system, Banister (1970) recommends that each lesson be tested in small groups to discover instructional faults. Field testing may reveal major and minor errors and ambiguities (Banister, 1970; Allan, et al., 1970). Implementation with small groups is necessary to provide insights for the initial modification and revision of the instructional system (Bunderson and Butts, 1969; Albracht, 1971). Koskey (1971) recommends field testing to obtain data on how the instructional system is working and to make adjustments and modifications which are needed to improve the system. After several experimental runs to gather feedback on the strategies, media, and logical framework of the programs and after making the required alterations, the instructional material can be prepared for general use (Banister, 1970).

The final step in the instructional systems approach is the acquisition of feedback which reflects instructional design effectiveness and behavioral objective achievement (Bunderson and Butts, 1969). According to Lumsdaine (1965) "how well the the program does, in fact, attain certain prospective outcomes, how well it teaches whatever it is calculated to teach . . . the extent to which its content is learned or the extent to which stated objectives are attained by students who use the program in a particular way" is a measure of effectiveness. Bunderson and Butts (1969) suggest that student behavior, performance capability, and responses to instructional events are sources of data useful in assessing the performance of an instructional program.

If evaluation is to be effective, the evaluative process must be merged with the teaching effort so that responses to particular teaching events can be ascertained (Bruner, 1967). Unless evaluation is based

upon specified "input," the evaluative effort is equivalent to "serendipity." Dean (1971) bases evaluation of the instructional system upon student learning which can be determined with a written test based upon instructional objectives. For Glaser (1966) and Haney and Ullmer (1970), evaluation of the instructional program is grounded in the measure of learner competency and the knowledge achieved in relation to the predetermined performance criteria. Culp and Lagowski (1971); Hoffman and Druger (1971); and Castleberry and Lagowski (1970), have extended the task of evaluation to include the analysis of attitude questionnaires and attitude scales. In addition to the assessment of achievement and attitude change, Elkins (1970) has expanded the evaluation instrument to include demonstrations of psychomotor achievement. Other sources for evaluative data include student questionnaire appraisal (Koskey, 1971; Cyrs and Lowenthal, 1970), written student comments (Koskey, 1971), student interviews (Cyrs and Lowenthal, 1970), instructor observations (Koskey, 1971), and instructor anecdotal records (Dean, 1971).

The key to the systems approach is "on going evaluation" leading to revision (Cyrs and Lowenthal, 1970). According to Canfield (1967), evaluation and the use of feedback to improve and refine the system is a major thrust of the instructional systems approach. Wooton (1971) refers to iteration, the cycle of implementation, evaluation, and revision of the instructional system as a hallmark of systematic instructional design.

In the instructional sequence there is an input-output relationship which involves the process of correcting for feedback information (Wooton, 1971). According to Churchman (1968),

> the input of curriculum demands a constant output of research and development pertaining to the rapidly changing contributions of various instructional media. The input of instruction is designed to bring about a certain output of student behavioral changes regarding their respective levels of acquired skills, knowledge, and attitudinal changes.

Belgard (1971), defines input to include entry behavior, developmental level, subject matter, teaching skills, technical aids, time schedule, and uncertainties while output involves performance analysis. The relationship between input and output which involves feedback, which effects modifications of input, which in turn affects output, results in the system being self-regulatory or self-correcting (Silvern, 1968; Kaufman, 1971).

Planning, organizing, designing, implementing, and evaluating learning situations and outcomes as well as making continued revisions to assure ongoing relevancy and practicality are the primary tasks of educators and the application of the tasks in the educational framework is "learning management" (Kaufman, 1971). According to Dean (1971), the program of deliberate educational planning which results in systematic instruction is "instructional management."

Though Glaser (1966) indicates that the instructional designer or educational technologist is a specialist who "hardly exists in our society," Bern (1967) reports that W. W. Charters considered the question of educational engineering as early as 1925. In 1960, Estes (1960) perceived the entire field of education as an "engineering discipline." Bern (1967) reports that several universities are offering courses in educational technology and the courses which are being offered in "human engineering and technology" provide training "related to complex electro-mechanical information and communication equipment design problems and applications."

CHAPTER III

METHOD OF RESEARCH

The development of systems approach instructional materials for the general studies biology course at Ball State University was selected for this research study. The course accommodates large numbers of students, the majority being freshmen, with a broad array of backgrounds and interests. Audio-tutorial instruction served as the basic mode into which systems for individualized instruction using technological resources were implemented.

Development, Implementation, Evaluation, and Revision Cycle

Three subject matter areas titled Birth, Birth Control, and Genetic Counseling were developed as a result of a needs assessment involving interviews of volunteer general studies students and expertise of two course coordinators, four doctoral teaching fellows, and four graduate teaching assistants. Interests of general studies students were established over two academic quarters through ten interview sessions with panels including four to six student members. Societal needs and basic content area principles were identified through expertise input.

The instructional materials were designed to guide student discovery. A variety of visual displays, investigatory exercises, and supplementary readings were included to broaden the scope of the subject matter. Whenever necessary, original visuals and investigatory exercises were

implemented. Staff decisions were reached to allow one week of class time for each of the main topics and to relate the subject matter as much as possible to human biology.

In their final implementation form, the content outlines of Birth, Birth Control, and Genetic Counseling are shown in Tables I, II, and III, respectively. The subdivisions of each of the subtopics were designed to accommodate a series of instructional strategies and media selections. A hierarchical structure which demanded appropriate instructional sequencing was implied in the subdivisions of each topic. This does not mean that the learning could not take place with a different sequence; other sequences could be of equal, more, or less effectiveness. The instructional sequence was selected by the author as the one most likely to facilitate easy and rapid learning of the particular instructional materials.

The flow chart which illustrates the systematic approach used in the design of the instructional materials is shown in Figure 2. The components of the flow chart, pilot study and evaluation analysis, provide for feedback which influenced revision and modification of instructional objectives, strategies, sequences, content areas, and media.

Based upon the content areas that were specified for the three instructional units, student behavioral objectives (Appendix A)[a] were written according to Mager (1962). The basic components of the objectives were (1) the terminal behavior or learning task; (2) the conditions under which the behavior was to be demonstrated or measured; and (3) the

[a]This appendix as well as all other appendices are on file in the Office of the Department of Biology, Ball State University, Muncie, Indiana 47306

TABLE I TOPIC: BIRTH

Subtopic (Instructional System)	Subdivisions (Instructional Sequence)
Early Development to Organ Formation	Developmental Process - Fertilization to Death
	Fertilization
	Cleavage to Gastrula
	Neurulation - Typical Organ Formation Process
Effects of Drugs and Disease on Development	Removing the Chick Embryo
	Anatomy of the 72 Hour Chick Embryo
	Careless Drug Use - A Tragedy of Human Development
	Examples of Disease on Human Development
	Effects of Maternal Fear and Tension on Human Development
Modes of Prenatal Nourishment	In Utero Relationship During Human Development
	Osmosis and Diffusion

TABLE II TOPIC: BIRTH CONTROL

Subtopics (Instructional Systems)	Subdivisions (Instructional Sequences)
Contraceptive Practices: Advantages, Disadvantages, and Mechanisms	Currently Used Contraceptives
	Mechanism of the Pill
	Sterilization
Modes of Reproduction	Asexual Reproduction
	Sexual Reproduction
Chromosome Anomaly Birth Defects	Meiosis
	Nondisjunction
	Translocation and Deletion
	Mutation

TABLE III TOPIC: GENETIC COUNSELING

Subtopics (Instructional Systems)	Subdivisions (Instructional Sequences)
Genetic Material - DNA	
Fetology	
Inheritance Patterns	Dominant-Recessive Inheritance
	Incomplete Dominance
	Human Applications
Selective Breeding	Sexual Modes
	Asexual Modes

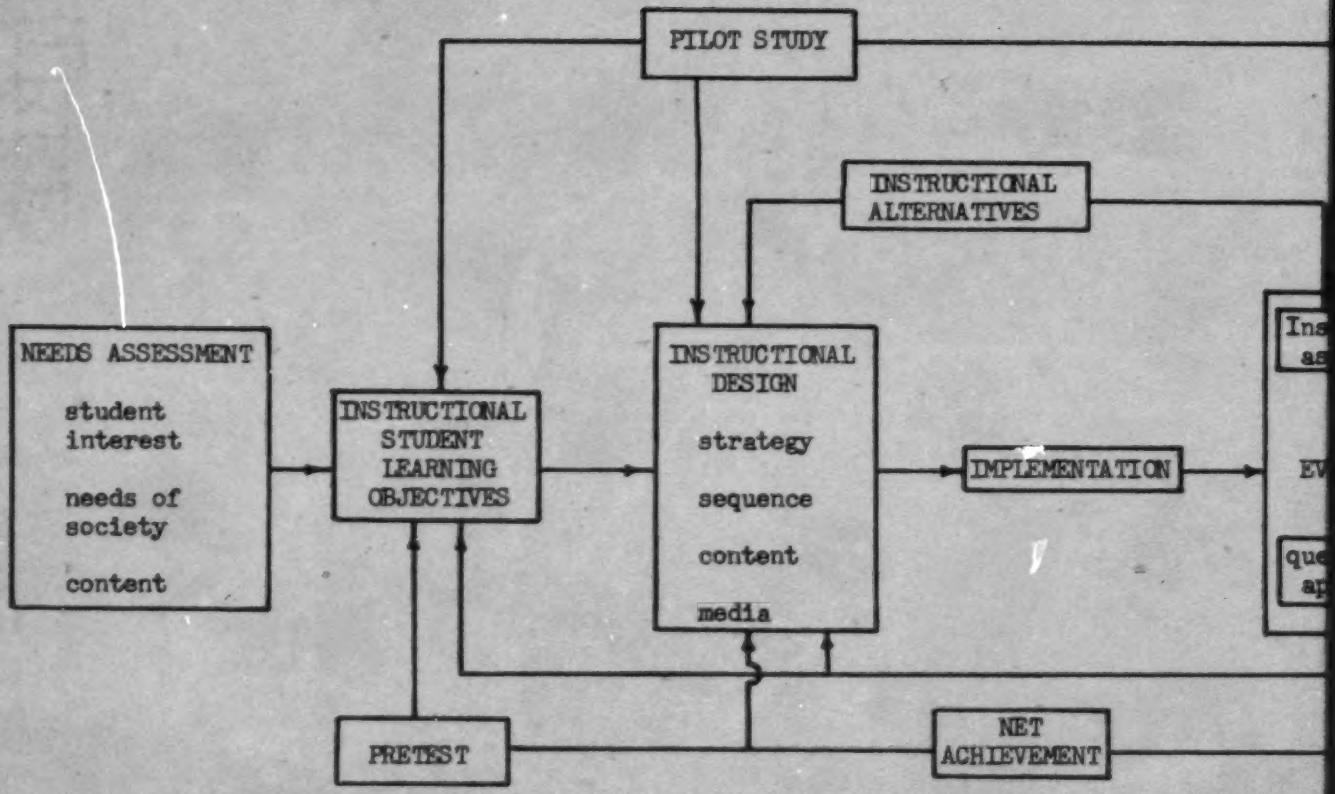
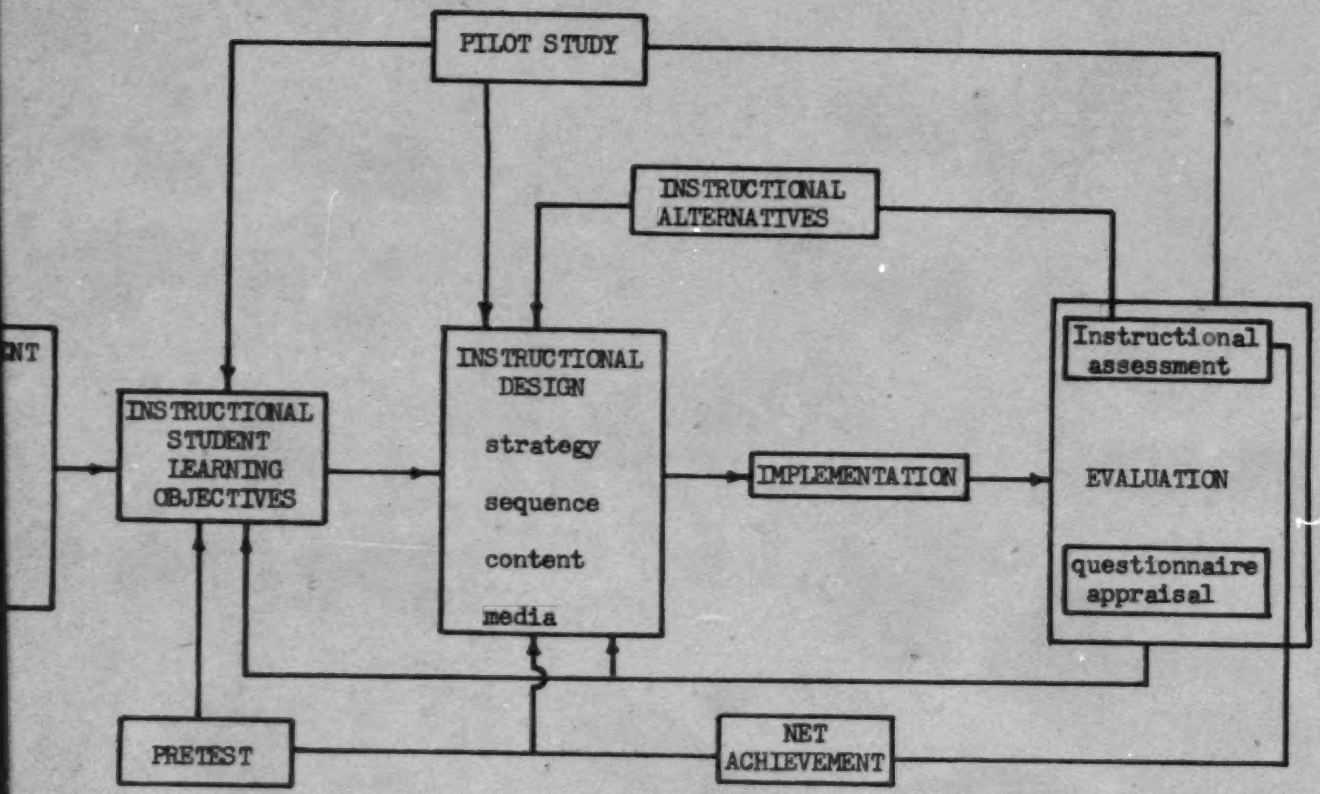


Figure 2. Systems Approach Instructional Design



ems Approach Instructional Design

standards of achievement. The final phases in establishing the systems approach included designing instructional strategies to enable students to accomplish the predetermined objectives and collecting evaluative feedback for revision directed toward enhancing the instructional effectiveness.

With the completion of the first draft, a pilot study of prototype materials was conducted with six regularly enrolled volunteer general studies students. The students in the pilot study progressed through the instructional materials frequently relying upon written instruction rather than audio tape recordings, referring to outline sketches rather than veritable visuals, and utilizing simulations rather than investigative involvements.

Student feedback concerning the instructional materials and the strategies was gathered through informal conversation and the instructional system effectiveness was established through the analysis of short answer response tests. Pilot study feedback gathered through informal conversation with the students and analysis of test data resulted in the confidence that the instructional materials adequately provided for student and societal needs.

The next consideration in the systems approach applied to the development of instructional materials was to evaluate the materials in the regular general studies biology course. As an economy measure, a staff decision was reached to implement a single unit, Birth, to serve as a model for feedback that would not only affect the design of the unit, Birth, but also affect the design of the units, Birth Control and Genetic Counseling.

With the guidance of the feedback gathered through the implementation of Birth, instructional materials for Birth Control and Genetic Counseling were prepared for implementation into the general studies biology course. In addition to revisions in the unit, Birth, and the preparation of Birth Control and Genetic Counseling for general studies use, a Learning Guide for each of the three instructional units was designed in an original format. Evaluation of the three instructional units assured the instructional effectiveness of the materials, indicated a high student assessment of the Learning Guide design, and resulted in a staff decision to shorten the unit Birth. In order to accommodate the student time requirement for completing the instructional materials of the unit, Birth, a subtopic, Cellular Function and Structure, was eliminated.

Learning Guide Design and Development

The Learning Guide for each instructional unit was designed to establish the setting, specify learning goals, direct system participation, engage the student in interaction with the instructional material, and provide a concise review of the material. The format of the Learning Guide used in the pilot study was styled after predecessor manuals which required responses to questions and statements such as "What is cleavage?" and "Identify two prominent structures in the 72 hour chick embryo."

As a result of pilot study feedback and evaluation based upon the preliminary implementation of the unit, Birth, into the general studies biology course, an original Learning Guide format evolved (Appendix B). A typical student remark which prompted a revision of the Learning

Guide style was "I'm not sure that my answers in the Learning Guide are correct." A second stimulus which influenced the development of a style Learning Guide resulted from a time study of student involvement in the instructional sequence. Ideally, the time required of the student to make a record of the instructional activities should be kept at a minimum. The concern was to maintain a high instructional intensity by avoiding time loss to less meaningful efforts such as keeping notes or summarizing learning activities. Thus, a Learning Guide was developed which was definitive and assuring to the student. Also, the new Learning Guide was designed to force student interaction and involvement with the instructional system while requiring a minimum of student time to make a record of the instructional experience.

A brief introductory statement and a list of student behavioral objectives (Appendix A) prefaced each unit in the new Learning Guide. To achieve the desired student interactions, a variety of question forms were incorporated. Each question type was specially constructed to reinforce and summarize a particular instructional event.

Matching questions were used in situations where several related statements or definitions were given in succession. In responding to a matching question, the student would record the answer quickly because only a single character was recorded. The matching question would also provide an accurate summary of the series of related statements because the items of two columns, terms and definitions, were already provided. Lastly, the matching question would reinforce the subject matter because the student's response would require an attending behavior.

Fill-in-the-blank questions were included to require the student

to interact with a single increment of instructional material. This type of question required a written statement of an idea, an equivalent response, an involvement which required a thought about the question statement and the statement required to complete the question. Another application of the fill-in-the-blank question required the student to supply one term of a series of terms. If the sequence of terms given in the stem of the question were different from the order of terms in the instructional event, the student had to interact with the material by sorting and comparing the given terms to be able to identify that which was missing. The student was able to answer the question only after the missing terms were identified.

Multiple choice format questions were included to require the student to select from possible alternatives, identify degrees of difference or similarity, and to reinforce an aspect of the instructional material. Selecting from alternatives is illustrated by the following example questions:

> The risk of having a child with Down's syndrome is approximately three times (greater/less) for a mother who already has one Down's syndrome child than for a mother who has not had a child with the anomaly.

and

> When dealing with incomplete dominance, the GENOTYPE (is/is not) immediately known by observing the PHENOTYPE.

Identifying degrees of difference or similarity is illustrated by the following question:

> The apparently small momentary effect of drugs taken over a long period of time would have:
> a. No effect on development
> b. A small effect on development
> c. A large effect on development

Reinforcing an aspect of the instructional material is illustrated by the following question:

> In contrast with the starfish egg cell, the following characteristics which can be assigned to the starfish sperm which distinguish the sperm from the egg are:
> a. mobility, small size, triangular shaped head, and long, whip-like tail
> b. no genetic material, mobility, small size, and triangular shaped head
> c. genetic material, mobility, size equal to the egg cell, and long whip-like tail.

In addition, multiple choice questions were used to call to the student's attention two aspects of a process, one being in the stem of the question, and the second being intermixed with three foils. This strategy is illustrated by the following question:

> In addition to the development of the nervous system (brain and spinal cord) during neurulation, a major organ and system which is also developing is the:
> a. kidney and excretory system
> b. lung and respiratory system
> c. heart and circulatory system.

True and false statements were used throughout the Learning Guide to emphasize a fact or principle, offer a brief summary, or provide a definition. Respective examples of the uses of true and false statements are:

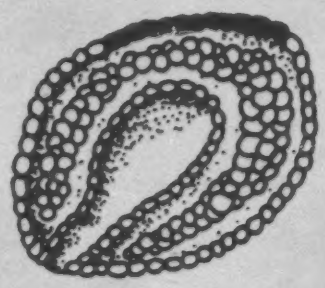
> TRUE FALSE The developing child has a personality; is sensitive to pain and responds to numerous stimuli such as maternal fear and anxiety.
>
> TRUE FALSE Three body activities that must be considered when the menstrual cycle is examined are the activities of the pituitary gland, the uterine lining, and the ovary.
>
> TRUE FALSE Fetology is an advancing phase of science with a primary focus on the study of human development and the regulation of human development.

All of the true and false statements were intended to be correct, that is,

answered "true." It was considered desirable that the student have a correct summary or definition rather than one which was incorrect. A statement could be incorrect for several reasons, omission, a degree of difference, or a negated verb which would be as unknown to the student. Thus if incorrect, the statement could be of little value as a summary or for purposes of review.

Application questions were used to provide the student with an opportunity to utilize newly acquired knowledge and make predictions. For example, after progressing through a learning sequence which described the formation, structure, and derivatives of a developmental stage, the application question provided for student response was:

> If the darkened cells of the gastrula, pictured at the right were surgically removed and development continued, the organ or system which might be affected in its development could be the:
> a. nervous system
> b. kidney
> c. liver



Problem solving questions frequently were used in the unit, Genetic Counseling, to enable the student to develop the logic and to practice the problem solving methodology of the geneticist or genetic counselor. Typical problem solving questions are illustrated by the following:

> Using the gene symbol I^R to represent red flower color and I^W to represent white flower color:
> a. the genotype of a red flower would be _____
> b. the genotype of a white flower would be _____
> c. the genotype of a pink flower would be _____
> d. the genotypes of the offspring of two pink flower color parent plants would be _____.

> If a father is Rh+ and the mother is Rh+, the highest

probability of having an Rh- factor baby is: (take into consideration all of the possible parental genotypes).

Tables were used in the Learning Guide to provide organization for recording the data of investigative activities and observations as well as condensing the characteristics of a lengthy descriptive presentation. The latter use of a table as a mode of illiciting student interaction with the instructional system is illustrated by the strategy employed to treat contraceptive methods in the Birth Control unit. As mechanisms, advantages and disadvantages of various contraceptive methods were considered using the audio tape presentation, the student was required to check mark appropriate tabular column and row intersections. Thus, at the conclusion of the audio presentation, the student would have a synoptic profile of three categories characterizing various contraceptive methods.

A bar graph profile was employed in the Learning Guide in conjunction with the instructional treatment of contraceptives. The graph served as a means of recording contraceptive method effectiveness as well as a comparative profile of contraceptive effectiveness. The abscissa of the graph was a scale of effectiveness and the ordinate represented various contraceptive methods.

Summative tables and figures as well as specially designed illustrations were included in the Learning Guide. Summative tables were included to provide the student with a brief overview of the details of a process such as the menstrual cycle, an outline of the steps involved in a problem solving process such as the probability of a mother giving birth to boys or girls, or a review of an instructional presentation illustrated by the expression of sex linked genes. Illustrations were

added to provide the student with visual summation of a process such as that illustrated by the use of a series of five, external and internal view perspective sketches of neurulation or of the effects of the menstrual cycle. Other uses of illustrations were a sequence sketch of a technique, general anatomical representations, and review of guided observations.

Lastly, programmed instruction was included in the Learning Guide as an instructional strategy to teach involved concepts such as the effects of the "Pill" on the menstrual cycle, osmosis and diffusion, and the DNA code. The program format was linear and designed according to the recommendations of Markle (1969), Espich and Williams (1967), and Lysaught and Williams (1963).

In its final form, the new Learning Guide presented a format of several question styles to engage the student in the instructional process as well as elicit and maintain the student's attending behavior. In addition to the variety of questions which were intended for the student's instructional experience, a variety of response requirements were imposed such as making an "X" next to the correct answer of a multiple choice format question, placing a circle around appropriate selections of a true and false question, shading in columns of a bar graph, or writing from one to several words in a blank.

Though the Learning Guide question types serving to conclude an instructional sequence were of a particular format, no assumption was made that the question format could not be different. Several question forms could have been used to conclude many of the instructional systems. The question type was often determined by the question format just

preceding or following as well as the author's judgment of the desired student interaction and participation. The author's maxim was to vary the stimulus by avoiding monotony, attempt to elicit the maximum amount of student involvement, and strive for creativity.

Audio Tape Design and Development

Audio tapes (Appendix C) were designed to provide narrative information, instructional direction, and student interaction with the instructional materials as well as with the Learning Guide. The technical teaching skills (Allen, 1967) such as establishing set, establishing frames of reference, illustrating and using examples, allowing for redundancy and repetition, asking questions, pre-cueing, and achieving closure were incorporated into the audio materials to enhance the effectiveness of the instructional strategy.

At the onset of each instructional subdivision, cognitive rapport was established by presenting a verbal sketch of ensuing instructional activities or by describing the context which provides a reason for the instructional activity. Examples taken from the audio scripts of Birth, and Genetic Counseling which illustrate the two techniques of establishing set are:

> The principles and concepts which center around a developmental event known as birth will be the major concern of today's study. Briefly, you will examine the phenomena of fertilization and the early developmental process that leads to the formation of organs and systems. Your attention will also be directed to the system and process by which the developing human being is nourished as well as examine the effects that drugs and disease may have on development.

and

> It is not unusual for parents to express a hope of having

> a child of a particular sex. How is sex in an offspring genetically determined? Years ago, some of the notions about how sex was determined were quite mystical. For example, one theory related sex to the moon phase at the time of conception . . . Another theory suggested that sex was determined by the uterine position occupied by the child during development. However, by the early 1900's, the Chromosome Theory of Sex Determination was established.

An excerpt from the audio script in the unit, Birth Control, which illustrates the establishment of appropriate frames of reference is:

> Despite the moral questions that are being raised, abortion as a birth control measure is gaining in popularity and acceptability. Though many legal and theological questions are still unresolved, it appears that various restraints which limit the application of abortion to special cases such as rape, incest, and therapeutic measures, will be abandoned in favor of more liberal practices.

Illustrating and using examples as an instructional technique in the unit, Birth, is evidenced by:

> Let us imagine that we are small enough to fit inside of the uterine tubes. Now, while you're standing in the uterine tube, an egg has just been released from the ovary and is caught in the uterine tube. The egg begins to be moved through the tube by a rhythmic pulsing. As the egg moves through the tube, it is encountered by a mass of sperm; one of the sperm cells penetrates the egg; the egg is now fertilized.

and in the unit, Birth Control, by:

> In the past, the potions for birth control were magically oriented. For example, one method of birth control was to "spit thrice in the mouth of a frog or eat bees." Another method prescribed that a woman take about one-half ounce of "powdered palm leaf and red chalk on the fourth day of menstruation.'

Allowing for redundancy and repetition was accomplished through the utilization of various media in the instructional sequence. The first encounter with that which was to be learned was intended to occur in the establishment of set. Subsequent encounters were intended to occur as the student participated in the instructional endeavor. The

The last encounter was intended to occur in the closure. For example, in the study of fertilization, the first encounter with that concept occurs in the audio presentation: "The life of a new individual begins when a living sperm cell penetrates a living egg cell; the phenomenon is known as conception or fertilization." As the instructional sequence progresses, the student (1) examines photos of human fertilization and microscope slides of fertilized and unfertilized starfish eggs; (2) compares the microscopic observations with Learning Guide illustrations; and (3) responds to Learning Guide questions which direct attention to similarities and differences among fertilized eggs. Lastly, the audio presentation recalls the importance of fertilization in the developmental process and the site in the uterus where the phenomenon occurs.

Asking questions in the audio presentation format was utilized as a method of achieving student attending behavior and as an aid to focus on the issue of the instructional sequence. For example, in the unit, Birth, a question sequence was:

> How then do foods, gases, wastes, and other materials such as drugs pass through the placenta? What is the mechanism of exchange between the mother and the developing child?

or in the unit, Birth Control, a question sequence was:

> How does it happen that the offspring receives a chromosome number equal to that of the parents? How is the chromosome number kept constant from generation to generation?

Asking questions was also a method of allowing for redundancy and repetition.

Pre-cueing was accomplished by informing the student that his responsibility after the completion of an instructional event would be

to respond to particular Learning Guide questions. Through the use of the pre-cueing technique, the student was alerted to prepare for a particular response task as well as to focus upon the important aspects of the instructional event.

Closure involved the incorporation of brief summaries at the conclusion of a particular instructional sequence. For example, at the end of a consideration of sex linked inheritance in the unit, Genetic Counseling, closure involved the following audio presentation:

> Thus, we have examined the pattern of sex inheritance, some special sex linked traits such as hemophilia and color blindness, and the phenomenon of probability which is the chance that a particular trait will be inherited.

Additional concerns in developing the audio materials were simplicity, uncluttered format, and logical organization (Davis, 1965). Also, every reference to a figure, chart, visual display, or activity was accompanied by verbal direction to aid the student in focusing attention on the meaningful dimension of the activity. In developing the audio tapes, nothing was left to chance regarding student observation or activity.

Instructional Unit Strategies

The three instructional units, Birth, Birth Control, and Genetic Counseling were each divided into subtopics which represented instructional systems. In turn, each subtopic or instructional system was divided into subdivisions which represented instructional sequences. The instructional sequences were developed through a series of instructional events which represented a single student activity such as answering one or more Learning Guide questions, observing a demonstration, or

conducting an investigative activity. The logic or reasoning underlying the inclusion and structuring of instructional sequences and systems was the instructional strategy. In all cases, the selection of an instructional event or sequence was based upon the attempt to maximize learning; however, in some cases, selection was tempered with expedience and economics.

Birth

The instructional unit, Birth, was set in the context of the recent discoveries of molecular biology, genetics, and developmental biology which make genetic engineering appear as an inevitable reality.

The scope of Birth was limited to prenatal development; however, to place that definite range of concern into perspective, the distinction between prenatal and post natal development was established with four frames of a linear program included in the Learning Guide. An earlier attempt using audio narration resulted in cumbersome and awkward verbal usage followed by the task of recording definitions in the Learning Guide. The programmed instruction was the more expeditious mode; it was brief, it provided an adequate explanation of the concept, and it resulted in an accurate record of the concept upon the completion of the self-instruction material.

The Picture Story of Human Development (Figure 3) was the second step in the instructional sequence concerned with the subdivision, Developmental Process - Fertilization to Death. The intention was to point out to the student a subtility that might have been overlooked, that development is a process that begins with fertilization and ends in death. As designed, the student would observe a visual display of

typical stages in the developmental process and a cassette tape would direct the observation and identification of significant features. The significant features of the demonstration were summarized in the Learning Guide by a nine item matching question to be subsequently completed by the student.

The instructional system, Early Development to Organ Formation, was continued in the next subdivision, Fertilization. In the first drafts of the unit, Birth, the strategy related to the process of fertilization focused upon the witnessing of the event of sea urchin fertilization. The strategy was modified because of several prohibitive aspects including student time involvement and the mechanics in maintaining viable sea urchin sperm and egg cells. The final strategy involved (1) the audio directed observation of a photo series of human fertilization (Figure 4); (2) a description of starfish sperm, unfertilized egg, and fertilized egg in the study carrel (Figure 5); (3) the microscopic examination of starfish unfertilized and fertilized eggs with reference to Learning Guide diagrams; and (4) the completion of two Learning Guide questions. The Learning questions were a multiple choice format question which contrasted starfish egg and sperm and the other a fill-in-the-blank question which contrasted the unfertilized and fertilized eggs.

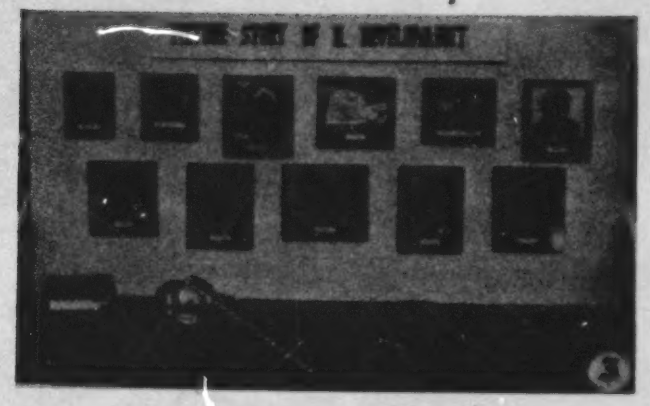
The instructional strategy underlying the fertilization study provided redundancy and repetition and attention to identify similarities and differences among the reproductive cells as well as the two states of the egg cell.

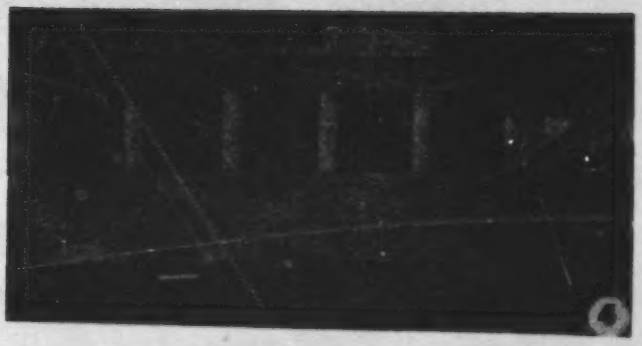
In instructing the student in the use of the microscope,

FIGURE 3. A directed observation photo display of human development from conception through death.

FIGURE 4. A directed observation photo display of human fertilization showing sperm, eggs, and the event of fertilization.

FIGURE 5. The study carrel for the unit, Birth, showing the materials used by the student during self-instruction.





experience has indicated that audio tape instructions are inadequate. As a consequence, the instructions for using the microscope were provided on a five inch by eight inch note card to which the student was referred. The "How to Use the Microscope" card (Appendix D) condensed several paragraphs of verbal explanation into eight concise statements.

The transition from the subdivision, Fertilization, to the subdivision, Cleavage to Gastrula (the early development of the fertilized egg) was accomplished by an instructional strategy involving an audio illustration and a Learning Guide diagram. The audio narration was designed to establish set by (1) informing the student that fertilization occurs in the upper third of the uterine tube and development occurs in association with the uterine wall and (2) presenting a question, "Developmentally, what has happened in the interim between fertilization and the time of implantation?" As the student listens to a description of interim development his attention is directed to the Learning Guide diagram of the female reproductive system which illustrates the site of fertilization and the route of the fertilized egg to the site of implantation.

The study of interim development involved the process of cleavage and the sequential formation of three early developmental stages, morula, blastula, and gastrula. As the student listens to an audio description of the interim developmental events, attention is directed to Learning Guide diagrams which illustrate the process. The diagrams were intended to not only illustrate the audio narration but also serve as a comparative reference for following student activities and to review the early developmental process. The instructional activities which ended the learning sequence of interim development involved a microscopic

examination of cleavage, morula, blastula, and gastrula using starfish development slides, plus a recommendation to view three dimensional models of the early developmental stages (Figure 6), and the response to five Learning Guide questions. The examination of starfish development was intended to result in redundancy and repetition through different media. The models were intended to serve to illustrate the three dimensional character of the stages. This aspect of organismic development is frequently overlooked when a study involves diagrams and microscopic examinations. The Learning Guide questions of multiple choice format and of fill-in-the-blank format required reflection upon the preceding learning activities and provided the student with a record of the activities.

The last instructional sequence in the system, Early Development to Organ Formation, involved Neurulation--A Typical Organ Formation Process. The instructional sequence involved referring the student to a Learning Guide table which would identify the organ and system derivatives of the gastrula tissues. The audio narration was designed to then pose the question "Can you visualize the profile of a human body if it consisted only of the structures that are derived from either (gastrula tissues) ectoderm, mesoderm, or endoderm?" The student was then directed to observe a sketch under the title, Body Parts from Gastrula Tissues (Figure 7). As a closing activity of this learning strategy, the student was asked to respond to the application question previously illustrated on page 41.

The instructional sequence continued by providing audio input which referred the student to Learning Guide sketches pertaining to the process of neurulation. The series of original neurulation sketches

were designed to show external and internal characteristics of the process in a three dimensional format. To enhance the student's concept of neurulation, the student was directed to observe the demonstration, Neural Development (Figure 8). The demonstration provided for the observation of frog neural development, external and internal anatomy. The external anatomy was microscopically observed using preserved early and late frog neural developmental stages. The internal features were observed using cross section and longitudinal section three dimensional models. The instructional sequence was concluded with a brief audio summative statement, closure, and a recommendation to complete four questions in the Learning Guide which would be repetitious of the audio closure.

The second instructional system, Effects of Drugs and Disease on Development, began with an instructional sequence involving the 72 hour chick embryo. The chick embryo was to serve as a living example of developmental advancement after neurulation. The 72 hour chick served as the biological specimen for the observation of brain, spinal cord, eye, limbs, and heart. In addition to illustrating early anatomical features, the chick embryo also served as a model for momentary effects of common drugs.

The first instructional sequence involved removing the chick embryo from its shell (Figure 9). Each student was directed to obtain a fertile egg that had undergone three days of development, remove the embryo and yolk from the shell, and examine the organism. The steps which the student was to follow during this instructional sequence were listed on an instruction note card, Removing the Chick Embryo (Appendix D).

FIGURE 6. Models of early developmental stages permitting the student to visualize the three dimensional character of cleavage and post cleavage stages.

FIGURE 7. A sketch indicating some tissues, organs, and systems which are derived from the respective gastrula tissues.

FIGURE 8. Neural stage microscopic and model observation which discloses external and internal features.

Instruction for the removal of the chick embryo was originally provided using a super 8 mm filmclip produced by the author. The narrated filmclip showed how the student was to (1) obtain an incubated egg; (2) candle the egg to determine the presence of a viable embryo; (3) break the egg shell by striking it on the edge of a finger bowl; and (4) pull apart the halves of the broken shell to release the contents. However, prohibitive costs for the replacement of frequently broken films, instructor time loss during film repair, and the pressure to shorten the student time involvement in the unit led to the abandonment of the filmclip. The filmclip was replaced by a more expeditious and economical strategy involving an eight frame series of 35 mm slides coordinated with an audio cassette narration. To complete the instructional sequence, a diagrammatic summary was included in the Learning Guide for student reference.

Experience with student operation of visual aid projectors has indicated that written instructions providing information for use are inadequate. Generally, students have bypassed reading written instruction in preference to fumbling with the equipment to get it to operate. In lieu of that experience, the instructions for operating the 35 mm slide projector were given on the audio tape preceding and following the narration of the slide series.

The instruction card itemizing the steps for the instructional sequence was included because it was experienced that students forget the order in which they are to proceed through a sequence unless verbal instruction is continuous. The summary card was designed to be carried by the student as a check list for the performance of a series of

activities to be completed away from the study carrel, away from a source of continuous audio instruction.

The instructional sequence involving the 72 hour chick embryo anatomy was implemented by using an audio narration and a Learning Guide diagram. The diagram was also intended to provide the student with subsequent review material covering this instructional sequence.

The instructional sequence concerned with drug effects on development was initiated by an audio narration which related the 72 hour chick embryo to five weeks of human development. The narration included comments on the social concerns of drug use, the lack of drug research information, and alluded to the devastating effects of drugs on a developing organism. The living chick embryo served as a model for the demonstration of immediate effects of either alcohol, barbituates, or amphetamines and nicotine on a living organism. The instructional events involved recording in a Learning Guide table the normal heart beat rate of the chick embryo, the application to the embryo heart of either alcohol, one of four barbituates, or one of three amphetamines, and the recording of the heart beat rate following such treatment. The student was then directed to apply nicotine to the external blood network of the chick embryo, and record the effects on the blood vessels. Closure of the instructional sequence was accomplished by audio tape by asking the student to extrapolate the observed drug effects to human development. Learning Guide questions were employed to direct the student in arriving at specific conclusions.

A case study of the thalidomide syndrome was employed to exemplify the tragedy of careless drug use. The instructional sequence included a

brief introductory audio narration, pre-cueing for a response to a Learning Guide question, and the reading of an excerpt (Appendix E) of the "Thalidomide Syndrome" (Taussic, 1962) which was clipped in the study carrel (Figure 5). The pre-cued question was designed to aid the student in focusing upon the essentials of the excerpt.

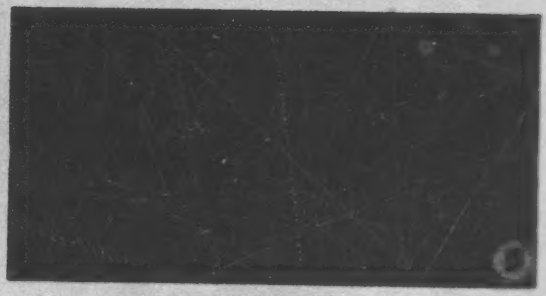
The instructional sequence on disease effects on human development included a brief introductory audio statement identifying certain critical diseases (German measles and venereal diseases, syphilis and gonorrhea) which affect human development; audio pre-cueing to aid the student in the critical observation of a photo demonstration; the observing the photo demonstration, Special Diseases and Development (Figure 10); and completing Learning Guide question which summarize the effects of disease on development. The format of the Learning Guide questions was of the fill-in-the-blank type and was designed to require the student to read the written message of the demonstration, read the Learning Guide question, compare the two (message and question), identify the missing or omitted elements, and fill in the word or words necessary to complete the questions. In addition to the consideration of the effects of venereal disease on development, a brief instructional sequence was provided on recognizing the symptoms of syphilis and gonorrhea in the adult body.

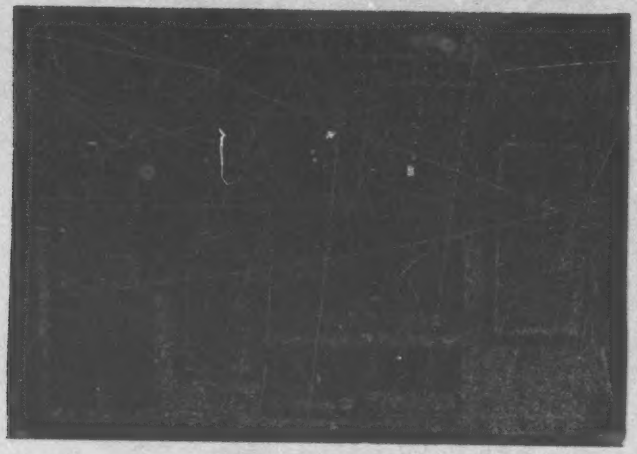
The instructional sequence dealing with the effects of maternal fear and anxiety on development was handled in a manner similar to the instructional sequence of the careless use of drugs. In the case of fear and anxiety, the reading excerpt (Appendix E) was taken from "What Doctors Now Know About Your Unborn Baby" (Brandt, 1967).

The last instructional system, Mode of Prenatal Nourishment,

FIGURE 9. An audio tape directed 35 mm slide demonstration of the technique for removing a chick embryo from the egg shell. Facilities are provided for the temporary incubation of fertilized eggs and for the egg candling process.

FIGURE 10. A photo display of special diseases which have a negative effect upon human development. Captions direct the student's attention to significant features of the photos.





was designed to include In Utero Relationship During Human Development and Osmosis and Diffusion. The instructional sequence, In Utero Relationship During Human Development, began by focusing on the moment of implantation. Set was established by making a comparison between the chick embryo relationship to the yolk and the need for a similar relationship during human development which provides for the attainment of nutriments. By audio questioning,

> How then do the foods, gases, wastes, and other materials such as drugs pass through the placenta? What is the mechanism of exchange between the mother and the developing child?

the student was prepared to enter an instructional sequence that began with seven frames of programmed instruction presented in the Learning Guide. The program was designed to develop the concepts of diffusion and osmosis. As in handling the presentation of prenatal and post natal development, the programmed instruction was a strategy to treat an involved concept, to provide for post study review, and to add variety to the total instructional system.

Following the completion of the programmed instruction, the next instructional event involved a student investigation exemplifying the diffusion of a material through a membrane, a phenomenon similar to that occurring between a mother and the developing child. A table was provided in the Learning Guide for the recording of student investigative observations. The student was then directed to complete a Learning Guide question which extrapolated the observations.

Closure for the instructional system, Mode of Prenatal Nourishment, was achieved through the use of a simulation of the in utero relationship between fetus and mother, umbilical circulation, and fetus to mother

osmosis and diffusion across the placental membranes (Figure 11). The student was directed by use of an instruction card (Appendix D) to prepare an osmosis indicator, observe the simulation, and respond to Learning Guide questions. The osmosis indicator was a starch solution which would turn blue in the presence of the simulated fetal blood, an iodine solution, which would diffuse through a simulated placenta. The simulated placenta was made from a semipermeable membrane. By depressing a button, the simulated blood could be seen to circulate through the simulated umbilical blood vessels. Students were pre-cued to complete Learning Guide fill-in-the-blank questions with descriptive information obtained through the reading of demonstration information cards. The completed questions were intended to summarize the structural and functional characteristics of the placenta, umbilical cord, amnion, and amniotic fluid.

Final closure for the instructional unit, Birth, was achieved by two devices, a brief audio statement and an examination of a series of prenatal photos and preserved fetuses. The audio statement was:

> In this study you have come a long way. You have discovered some of the early events of development, how a single fertilized egg cell can multiply and develop into numerous complex organs and systems and you have discovered some of the factors that can affect normal development as well as how the developing child is nourished.

The prenatal photos and preserved fetuses were incorporated into a demonstration, The First Nine Months (Figure 12) which illustrated the human in utero developmental process.

Birth Control

The temper for the instructional unit, Birth Control, was set in

FIGURE 11. A simulation of the *in utero* fetus to mother relationship which enables the student to witness the fetus to mother osmotic process. Captions provide information about the amnion, amniotic fluid, umbilical cord, and placenta. Facilities are provided which enable the student to prepare an osmosis indicator solution.

FIGURE 12. A photo display of *in utero* human development supplemented with specimens of miscarried fetuses.

the concern for the effects of a rising population and the increasing trend for family planning to improve the health level of society.

The first instructional system used in this unit was Contraceptive Practices. It was begun by an audio tape reflection upon primitive contraceptive methods which relied upon magical potions. With set established, the instructional sequence was designed around (1) the use of an audio description of the advantages, disadvantages, and mechanisms of currently used contraceptives and (2) the student completion of a summative table and bar graph in the Learning Guide. The strategy underlying this instructional combination was the same as that previously discussed under Learning Guide Design and Development.

The Mechanism of the "Pill" was a complex instructional sequence that began with the question of how "female hormone" contraceptives function. Consideration of the question on female hormone contraception led to a concern for the examination of the female reproductive system. The study of the female reproductive system was accomplished through (1) an audio description of the functions of the major structures which were diagrammed in the Learning Guide and (2) the completion of an eight item matching question relating structure and function. The components of this phase of the instructional sequence were designed to require student interaction with the audio presentation and to provide a review of the instructional material.

The second phase of the instructional sequence was designed to direct the students through a diagram of the menstrual cycle, the audio presentation described the events as the student observed a Learning Guide diagram depicting the events. The instructional event was concluded with a reference to a summary of the menstrual cycle in the Learning

Guide and supported by a directive to answer questions in the Learning Guide. The questions, true and false, matching, and multiple choice formats, were designed to elicit student interaction with the audio presentation.

The last component of the instructional sequence, Mechanism of the Pill, employed six frames of programmed instruction. This program was designed to teach the function of the Pill as a contraceptive. Upon completion, the programmed instruction could be used to facilitate student review.

The subdivision, Sterilization, was the last sequence in the instructional system, Contraceptive Practices. Set was established by relating sterilization to widespread use in heavily populated countries. Advantages and disadvantages of sterilization as well as a description of methods of male and female sterilization were presented through the audio media. Learning Guide diagrams were included in the design to help the student visualize the procedures involved in surgical sterilization. Alternate methods of sterilization, their advantages and disadvantages were incorporated as a dimension of the instructional sequence. The last student activity that was planned required the completion of five Learning Guide questions of fill-in-the-blank, true and false, and multiple choice formats. The questions were designed to serve as a summary of the audio presentation.

Closure using the audio mode reflected upon each of the instruction sequences which were incorporated into the instructional system, Contraceptive Practices. The audio presentation effecting closure was:

> So far in this study, various methods of contraception . . . have been examined. Advantages and disadvantages . . . have

> been considered. Also . . . the contraceptive effect of the "Pill," the events of the menstrual cycle . . . the principle for rhythm . . . contraception through sterilization . . . was reviewed.

The instructional system, Modes of Reproduction, was designed to relate the instructional systems, Contraceptive Practices and Chromosome Anomaly Birth Defects as well as to involve the student with the biological concept of organismic reproduction. Using the audio mode, set was established for the instructional sequence, Asexual Reproduction, in the closure of Contraceptive Practices. Set was established as follows:

> In general, it appears that the ability to generate offspring, a vital characteristic of living organisms, can be frustrated with a variety of effective methods. But, what is the generative potential of an individual? How do organisms reproduce? Is there any variation among organisms in their method of perpetuation?

The intended strategy was to confront the student with several questions which were designed to arouse attentiveness to the often "taken for granted" vital process of reproduction.

The instructional sequence was continued with an audio tape directed observation of an asexually reproducing plant, Bryophyllum pinnatum (Figure 13). The demonstration was designed to focus the student's attention upon a parent plant generating offspring plants that would mature into plants genetically identical to the parent plant. The advantages and disadvantages of asexual reproduction were considered by reflecting upon examples taken from the agricultural industry such as the Irish potato and the 1845 potato blight. The instructional sequence was completed with a direction to respond to four Learning Guide questions which were designed to capsulize the major ideas about asexual reproduction.

The instructional sequence, Sexual Reproduction, was initiated with an audio tape presentation contrasting asexually and sexually produced offspring in terms of parental resemblance. The tape presentation was:

> The progeny consequent to the sexual reproductive mode are not replicas of the parents . . . [they] have unique combinations of features which render them 'new.'

The next event in the instructional sequence was the audio tape directed observation of a guppy population to reinforce the concept of variation as a feature of sexually produced individuals (Figure 14). Students were directed to identify guppy parent characteristics and compare the characteristics with similar features of several offspring. To assure the student's interaction with the demonstration, the student was given the task of recording guppy parent characteristics in a Learning Guide table. The specific characteristics included in the table were the number and location of body spots and the shape and color of the tail. The student was then instructed to complete nine fill-in-the-blank statements which served to indicate the frequency of a parental characteristic appearing in the offspring. Closure was established with the completion of a matching question contrasting the features, advantages and disadvantages of asexual and sexual reproduction. The strategy underlying this instructional event was to reinforce the audio presentation statement that offspring, sexually produced, are similar to but different from their parents.

The last instructional event in the sequence, Sexual Reproduction, was designed to direct the student's attention to the commonness of sexual reproduction in the biological world. Set was established using an audio tape presentation which identified examples of sexual

reproduction. The design of the instructional event continued through the audio mode by pre-cueing the student for the completion of a Learning Guide table, Modes of Sexual Reproduction. The table was designed to summarize the observation of a demonstration depicting various modes of sexual reproduction (Figure 15). The Learning Guide table identified each example of sexual reproduction shown in the demonstration, required the student to identify the organismic kingdom which was represented by the example, and provide a brief description of the reproductive interaction, for example conjugation. The demonstration was provided in two parts, a photo-sketch display of lower organismic levels and a super 8 mm filmclip of various levels of vertebrate reproduction. Information for the photo-sketch portion of the demonstration was provided through short captions; the filmclip portion was narrated with an audio tape. The filmclip, Sexual Reproduction, produced by the author, depicted the reproductive patterns of the Japanese medaka (fish), Oryzias latipes; African clawed frog, Xenopus laevis; and Japanese quail, Coturnix coturnix. The organisms were selected for the exemplary filmclip because of their availability and readiness to mate. Closure for the instructional sequence was achieved with a summative fill-in-the-blank question in the Learning Guide and by an audio tape designed to be redundant.

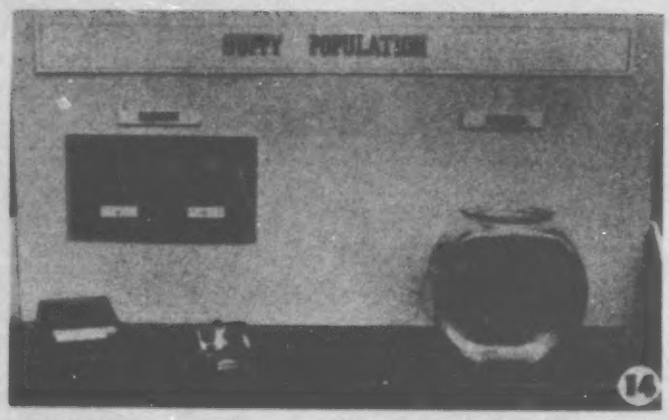
The last instructional system of the unit, Birth Control, was concerned with the subtopic, Chromosome Anomaly Birth Defects. This subtopic was developed to emphasize a need for birth control when congenital defects are likely to occur. The introductory instructional sequence involved meiosis. The set for meiosis was established by calling to the attention of the student that facilitation of "sexual reproduction involves a mutual interaction of a male and female which

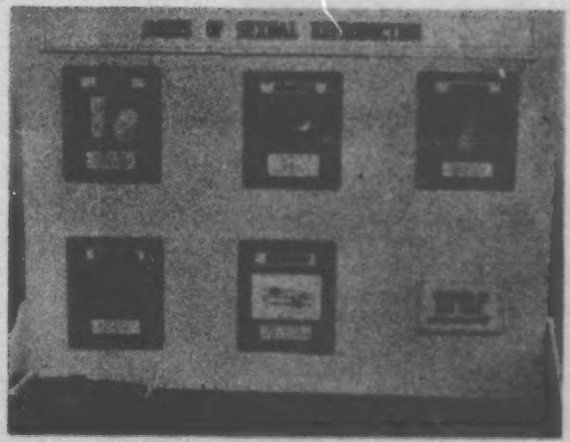
FIGURE 13. A directed observation of an example of asexual reproduction.

FIGURE 14. A directed observation of parent-offspring differences in guppies. The observation is an example of parent-offspring differences resulting from sexual reproduction.

FIGURE 15. A photo display and audio tape narrated film clip of organismic interactions associated with the process of sexual reproduction. The photo display treats lower forms of life. The film clip treats the vertebrate forms, fish, amphibians, and birds.

ASEXUAL REPRODUCTION
13


GUPPY POPULATION
14



15

assures the fertilization of the egg" and that within the sperm and egg are structures carrying "the information that prescribes the expression of inherited traits." The structures in the cells were identified as chromosomes and the student attention was directed to a supplementary sheet which was placed in the study carrel, Chromosome Types in Man (Appendix E).

The audio tape presentation on the Chromosome Types in Man was designed in conjunction with seven Learning Guide questions. The questions were of fill-in-the-blank and multiple choice formats and were designed to illustrate, reinforce, and summarize the necessity of chromosome reduction preceding fertilization. The audio tape closure method is illustrated by:

> To maintain a constant chromosome number from generation to generation, parent reproductive cells are produced by a special cell formation process, meiosis, whereby the sperm and egg, as the case may be, receives only one member of each pair of chromosomes.

The strategy underlying the development of the development of the concept, meiosis, and the necessity of chromosome reduction preceding each generation was to establish a point of departure from the normal chromosome division to the abnormal. An audio tape presentation of the normal chromosome division process was designed to establish set for the atypical chromosome division, nondisjunction.

The instructional sequence, Nondisjunction, was designed to involve treatments of somatic and sex chromosome nondisjunctions. The example of the consequence of somatic chromosome nondisjunction was mongoloid development. A demonstration, Mongoloid Development (Figure 16) and pre-cued Learning Guide questions served as the media for

instruction. A partially completed fill-in-the-blank question was designed to stimulate student interaction with the demonstration. Because the items given in partial completion of the fill-in-the-blank question were in a different order than these given by the display, the students were required to identify given and missing items before completing the question. Thus, the question required involvement rather than a mechanical copying process. Other Learning Guide questions of fill-in-the-blank and multiple choice formats required examination and interpretation of karyotype and frequency-of-occurrence tables. All of the questions were designed to also serve as summary and review techniques for the observation exercise.

Sex chromosome nondisjunctions were exemplified by common anomalies, Klinefelter's and Turner's syndromes. The instructional design for the treatment of Klinefelter's and Turner's syndrome included the audio tape explanation of chromosome nondisjunctions in the formation of egg and sperm cells. The audio presentation was developed to elucidate tables in the Learning Guide which in turn served to illustrate the various nondisjunction combinations that could produce Klinefelter's or Turner's syndromes. The tables also summarized the characteristics of both syndromes. A final activity developed for the consideration of Klinefelter's and Turner's syndromes was a three part fill-in-the-blank question. The question was designed to involve the student in contrasting (1) chromosome complements of the respective anomalies; (2) sex of hypothetical patients; and (3) parental origination of the nondisjunction.

Following the characterizations of the sex chromosome anomalies, the instructional sequence was designed to include methods of sex

chromosome nondisjunction identification. Three methods of sex chromosome nondisjunction identification were considered at a demonstration, Barr Bodies and Nondisjunction (Figure 17). The methods demonstrated were cheek cell Barr bodies, white blood cell drumsticks, and fingerprint ridge numbers. Instructions related to the demonstration were provided through pre-cued Learning Guide questions. These questions were designed to elicit student interaction and involvement with the photo caption and microscope slide examination display. The instructional strategy was similar to that employed for the treatment of mongolism.

The last instructional event in the sequence, Nondisjunction, was designed to extend the limits of the nondisjunction concept to organisms other than man. To accomplish this instructional sequence the student listened to an audio tape narrated demonstration, Nondisjunction in Organisms (Figure 18). The demonstration included a plant, Datura, and a chimpanzee. The observation was climaxed with a directive to complete three Learning Guide questions which were designed to summarize nondisjunction in organisms other than man. The question formats were fill-in-the-blank and true or false.

A third instructional sequence, Translocation and Deletion, was included in the design of Chromosome Anomaly Birth Defects. This sequence was added to provide a new dimension to the concept of congenital defects resulting from chromosome abnormalities. Set was established with the following audio tape presentation:

> . . . nondisjunction during meiosis is not the only kind of known chromosome anomaly. Chromosome deletions or chromosome translocations are also important causes of congenital defects.

The sequence was continued with a reference to study carrel printed materials on Chromosome Deletions and Translocations (Appendix E). The supplementary materials were designed to illustrate a deletion karyotype, "Cat's cry" syndrome and a translocation karyotype, Trisomy 15/21. The syndrome of each chromosome anomaly was described and closure was achieved with a matching question in the Learning Guide. The question was designed to require the student to match the terms "Cat's cry" syndrome and Trisomy 15/21 with syndrome characteristics and definitions. Thus, the question not only provided a definition of the two chromosome anomalies but it also provided a summary of the respective syndromes.

The concluding instructional sequence in the instructional system titled Birth Control involved the causes and effects of gene mutation. Set was established by an audio tape description of a mutation as a sudden unexpected genetic change. The instructional sequence was continued with descriptions of several common defects caused by gene mutation. The first mutation caused defect to be considered was sickle cell anemia. The student was directed to microscopically examine and contrast normal and sickle cell anemia blood sample slides at his study carrel (Figure 19). The symptoms of sickle cell anemia were disclosed and the student was then directed to observe a demonstration on sickle cell anemia (Figure 20). The demonstration displayed (1) a photograph of the sickle cell anemia blood cells; (2) a photograph of a symptom characteristic; and (3) an excerpt from an article. The article excerpt discussed research efforts which have been directed toward the control of the disease. The instructional sequence was continued with an audio description of albinism, a common mutation effect, and a directive for the

student to observe a demonstration pertaining to albinism (Figure 21). The deomonstration displayed photographed examples of albinism in plants, fish, amphibians, reptiles, birds, and in mammals including mice, gorillas, and man.

The last instructional event in the instructional sequence, Mutation, was initiated with an audio tape description of diseases in man caused by gene mutation. Among the diseases considered were gout, phenylketonuria, and Huntington's chorea. Closure for the instructional sequence was achieved by directing the student to complete five Learning Guide questions which were presented in fill-in-the-blank and matching formats. The questions were designed to provide a definition of mutation and characteristic effects of each of the maladies.

The unit, Birth Control, was concluded with a statement which was designed to serve a dual purpose, to provide closure for this topic and to establish set for the next instructional unit, Genetic Counseling. The statement was:

> With the increasing sophistication of scientific research, the tragedies associated with genetic diseases are being diminished through the efforts of counseling agencies which perform analysis and make available to prospective parents information concerning their chances of transmitting genetic defects to their children.

Genetic Counseling

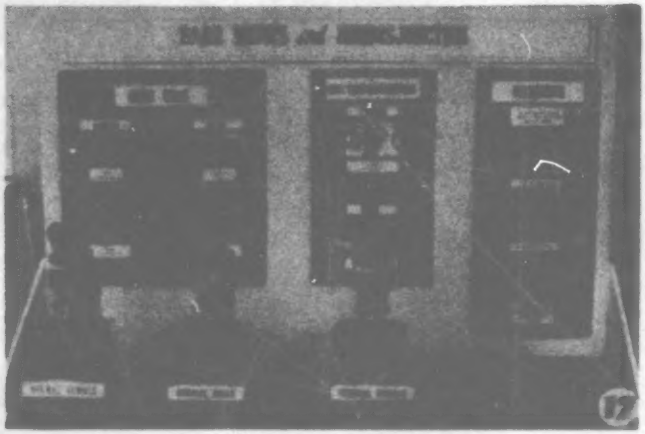
The instructional unit, Genetic Counseling, included four instrucal systems, Genetic Material - DNA, Fetology, Inheritance Patterns, and Selective Breeding. Inheritance Patterns, and Selective Breeding. Inheritance patterns received the major focus in the instructional unit, while Genetic Material - DNA, Fetology, and Selective Breeding were

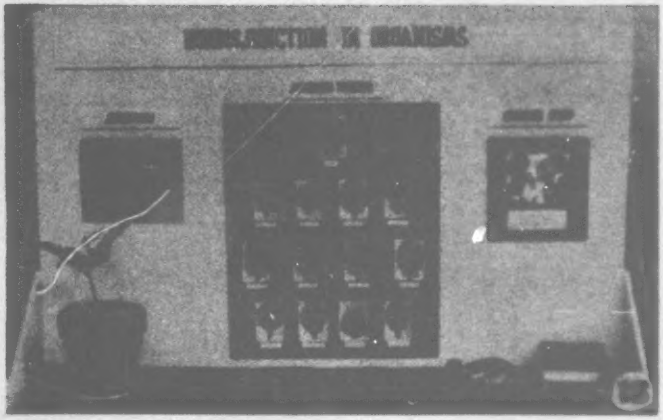
FIGURE 16. The display of mongoloid development demonstrates the typical mongoloid features, the mongoloid karyotype, the frequency of mongoloid occurrence with respect to maternal age, and the effects of a recently synthesized drug which alleviates the mongoloid symptoms.

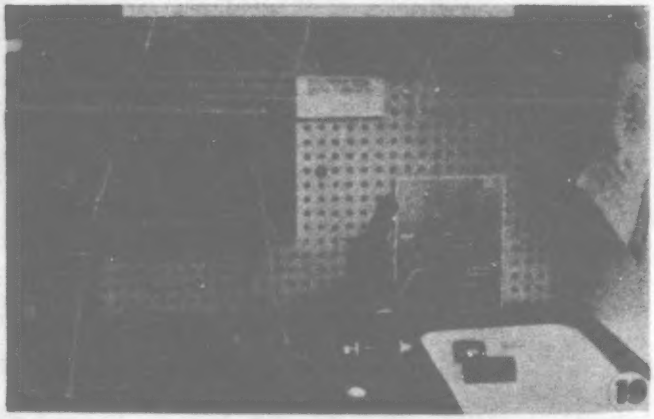
FIGURE 17. The microscopic and photographic demonstration of diagnostic symptoms of sex chromatin nondisjunctions.

FIGURE 18. A directed observation of examples of nondisjunction in organisms other than man. The example of nondisjunction in plants is a Jimsonweed and in animals, a chimpanzee.

FIGURE 19. The study carrel for the unit, Birth Control, showing the materials used by the student during self-instruction.







included to broaden the unit's scope. Genetic Material - DNA was designed to provide a theoretical background for the study of inheritance; Fetology was included to treat an emerging field of fetal medicine concerned with the treatment of congenital defects; and Selective Breeding was added to illustrate some methods man has employed to artificially control genetic expression.

Set for the unit was established by having the student read an excerpt which described the anxiety of parents seeking genetic counseling about their chances of having a second child with cystic fibrosis (Augenstein, 1969). Building upon this reading activity, the instructional sequence, Genetic Material - DNA, was initiated by directing the student's attention to the nature of the gene and the feasibility of future gene regulation. The introduction to the sequence was reinforced by the following audio presentation:

> Though research to avert abnormal human development due to a defective inheritance is in its infancy, the inheritance of bacteria can now be regulated. In time, it may become possible to correct faulty genes in man and thus enable man to prevent and/or correct congenital abnormalities.

The next step in the design of the instructional sequence was a directive to the student to complete fourteen frames of linear programmed instruction which was included in the Learning Guide. The programmed instruction was concerned with the structure and code of the hereditary material, DNA. The final frames of the Programmed instruction dealt with the potential to correct faulty DNA structure as a means of birth defect prevention.

Programmed instruction was selected as the instructional medium for the involved concept, DNA, because the method was expeditious and

effective as a teaching tool. The author found from pilot study evaluation that the programmed instruction mode was more effective than an audio tape presentation and required less student time and effort.

Upon the completion of Genetic Material - DNA, set for the instructional sequence was established with the following audio statement:

> Until it is possible to conduct an effective program of altering the genetic code to correct defective genes that cause abnormal development, alternative avenues of birth defect correction must be explored. A number of medical specialists known as fetologists have been developing and perfecting techniques to probe the world of the fetus, to detect genetic defects, and to do something about them.

Current and future fetological studies which were briefly considered using the audio medium were exemplified with case study readings from Brandt (1967) "What Doctors Now Know About Your Unborn Baby" (Appendix E). The audio tape presentation followed by case study readings were combined into a strategy to effect repetition and redundancy. Following this portion of the instructional sequence, the student was directed to respond to Learning Guide questions. The questions were intended to be synoptic of the instructional sequence and were designed in four styles: true and false, multiple choice, fill-in-the-blank, and table completion. A table was designed to be completed by placing a check mark in one of two columns which were intersected by a listing of seven capabilities of fetological medicine. The columns of the table were respectively titled current and future capabilities.

The final instructional event in the sequence, Fetology, was focused on a specialized fetological endeavor, in vitro conception and development. The audio tape related the progress of efforts involving in vitro conception. A demonstration, Development Under Artificial

Conditions (Figure 22), was used to elucidate to the progress of *in vitro* development of unborn sheep excised from the womb. Photos of unborn sheep illustrated their gestation period in an artificial womb and eventual release for a normal life. The demonstration of *in vitro* incubation of chick embryos provided additional testimony for the future possibility of human development under artificial conditions. This instructional event was concluded with a directive to the student to conplete a multiple choice format question which prognosticated the value of development in artificial wombs. Closure for the instructional sequence was achieved by a brief summative audio tape statement:

> The highlights of a new science, fetology, has been explored. The matter of heredity, DNA, its coded information which is expressed in the traits of inheritance and how the coded information may be regulated has been reviewed. And, the value of genetic counseling . . . has been considered.

The major instructional system of the unit, Genetic Counseling, was initiated with the instructional sequence, Dominant-Recessive Inheritance. Dominant-Recessive Inheritance was selected as the first sequence because it represents the basic mode of inheritance. Once mastered by the student, the principles of inheritance could readily serve as a model for the study of other modes of inheritance.

The instructional sequence, Dominant-Recessive Inheritance, was set with the proposal of three audio questions:

> Now, on what basis does the genetic counselor make his predictions? How is it possible to predict that a family can expect half of the children to be colorblind or that they have a 25% chance of having children with phenylketonuria, or microcephyaly? Can you answer the questions?

The three questions were followed up with a demonstration of dominant-recessive inheritance, an explanation of the exemplary genetic

expression, and a series of application problems which utilize the explanations.

The demonstration of dominant-recessive inheritance involved the observation of stem color, red or green, in three generations of sorghum; parents, first generation offspring, and second generation offspring (Figure 23). While observing the sorghum generations, the student was asked to count the number of red and green stem individuals representing each generation. The student was then directed to record the number of each type of individual in a Learning Guide table. With the audio medium, the student's attentiveness was directed to the tabular accounting in anticipation of the forthcoming explanation of stem color inheritance. The explanation of stem color inheritance involved a questioning technique intended to enhance attending behavior. The following represent some of the questions included in the explanation:

> Is there an explanation for red stem and green stem parents producing only red stem offspring? Can you explain why the hidden trait green, of the F_1 generation reappeared in the F_2 generation?

The audio tape explanation of sorghum heredity was continued with an analysis of the recorded data. In conjunction with the analysis, a Learning Guide figure was provided to correlate the student observation of stem color inheritance with the presence of genes. The figure was designed to also serve as a review of the sorghum heredity demonstration and as a concise summary of the audio tape explanation.

The concept of chance was introduced as a sequel to the analysis of sorghum stem color inheritance. This concept was developed with an audio tape directed examination of a Learning Guide figure which depicted the inheritance of traits as a consequence of gene random

FIGURE 20. A photo display exemplifying the diagnostic features of sickle cell anemia.

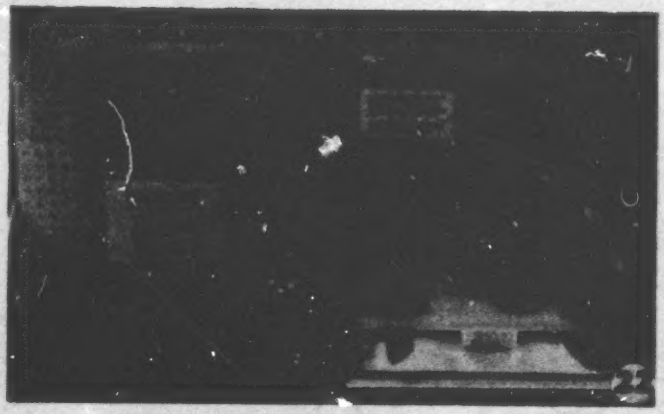
FIGURE 21. A photo display featuring examples of albinism among plants and animals. Representing the plant kingdom is corn. The animal kingdom is represented by one example of each vertebrate class.

FIGURE 22. The demonstration of development under artificial conditions of a lamb, shown in the photo at the left, and a chick, shown living *in vitro* development in the incubator at the right.

FIGURE 23. A directed observation of an investigative study of three generations of sorghum inheritance.

MUTATION DISEASES

MUTATION DISEASES
ALBINISM



assortment. The figure was designed to not only illustrate the audio presentation but to serve as a summative review resource.

The next instructional event in the sequence was to synthesize a concise symbolic expression of inheritance by correlating (1) the observation of sorghum stem color inheritance; (2) the explanation associating genes with inheritable traits; and (3) the concept of chance. To aid the student in this synthesis, an audio tape presentation was designed in conjunction with a Learning Guide figure. The figure was a symbolically designed illustration of the sorghum inheritance demonstration. To reinforce the symbolic account of dominant-recessive inheritance, three practice exercises were included as a student self-test. The first exercise presented a hypothetical inheritance problem and provided the initial steps toward a solution which the student was directed to complete the solution. The second exercise presented a hypothetical inheritance problem and provided the final steps in its solution; the student was instructed to compute the initial steps. The last exercise presented a hypothetical inheritance problem and directed the student to calculate the solution with no assitance provided. The exercises were designed to develop inheritance problem solving skills in a stepwise manner culminating in mastery of the methodology.

The subsequent instructional event was divided into two sections providing for (1) summation and review and (2) application. In the first section, the student was directed to read a brief summative statement and to complete three Learning Guide questions. The summative statement was a review of dominant-recessive inheritance. The questions

using multiple choice and matching formats were designed to summarize inheritance terminology. The second section of the instructional event was intended to extend the principles of inheritance to make genetic predictions about the genetic constitution of offspring and parents. The stimulus for this application situation was provided by directing the student to read an excerpt recounting the anxious moments of a young couple seeking the advice of a genetic counselor, being concerned about the probability of having a second child afflicted with amaurotic idiocy (Appendix E). The culmination of the application section was a series of true and false statements incorporated into a single question framework. Each true and false statement in the series was designed to require the student to utilize at least one principle of dominant-recessive inheritance. Also, the series was arranged to become progressively more complex.

The final instructional event on Dominant-Recessive Inheritance involved the reading of brief supplementary materials (approximately 500 words) which focused upon the inheritance of genetic defects (Appendix E). One of the readings was directed toward breakthroughs in the detection of disease causing recessive genes. The other reading provided a partial list of inheritable recessive gene defects.

The second instructional sequence, Incomplete Dominance, was succinctly introduced with an audio tape presentation. The presentation implied that the principles underlying dominant-recessive inheritance were applicable to incomplete dominance. The student was then directed to observe the demonstration, Incomplete Dominance (Figure 24). The demonstration was designed to direct the student's attention to examples of incomplete dominance and to contrast incomplete dominance and dominant-

recessive inheritance. With the completion of the audio tape directed observation, the student was required to respond to three Learning Guide questions which were designed to emphasize the differences between incomplete dominance and dominant-recessive inheritance. The questions also provided the student with the opportunity to evaluate self-competence in applying inheritance principles.

The final event in the instructional sequence on Incomplete Dominance was designed to reinforce the differences between incomplete dominance and dominant-recessive inheritance. The student was instructed to observe an audio directed demonstration, Inheritance Model (Figure 25). The demonstration analogously compared incomplete dominance and dominant-recessive inheritance. To summarize the examination of the model, the student was in instructed to record the observations in a Learning Guide table. As a self-check for the student, a seven part question was included in the Learning Guide. The student was instructed to identify each of the seven statements as either characteristic of incomplete dominance or dominant-recessive inheritance.

Closure for the instructional sequence, Incomplete Dominance, was achieved by a concise audio summative statement characterizing incomplete dominance in comparison with dominant-recessive inheritance.

The final instructional sequence in the system of Inheritance Patterns was concerned with Human Applications. The establishment of set was accomplished by an audio tape recounting the development of fundamental principles of inheritance and by proposing the opportunity to apply the tenets to human inheritance.

The first instructional event was to examine supplementary

materials, "Four Human Traits" (Appendix E). Relying upon the supplementary reading materials and using a mirror placed in the study carrel (Figure 26), the student was directed to observe a few of the thousands of his inherited traits. The student was instructed to use a Learning Guide table to record the phenotype of his own traits as well as the possible genotype for each of the traits. To complete the instructional event, the student was asked to solve an inheritance problem. The problem required the student to select a trait from the Learning Guide table of his trait expressions, apply the principles of inheritance, and predict the chance that the same phenotype would appear in an offspring. The conditions underlying the problem were that one parent trait expression was similar to that of the student's and the other parent was heterozygous for the trait.

The instructional sequence was continued with the examination of less obvious inheritance expressions such as the ability to taste phenylthiocarbamide, PTC. Another concern was for the inheritance of blood type antigens, Rh-factor and ABO.

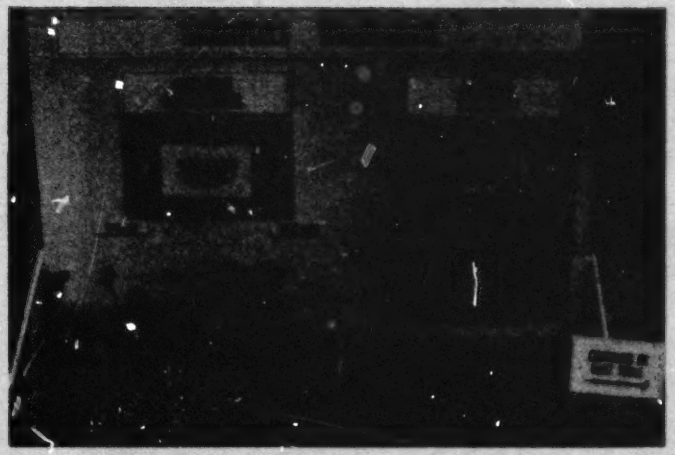
The concept of Rh- inheritance was developed using the audio medium. Reinforcement for the fetological complications was provided with exemplary case studies incorporated into the supplementary readings (Appendix E). To augment the reinforcement, the student was instructed to solve a Learning Guide problem which pertained to the inheritance of the Rh-factor. A fill-in-the-blank question was also included in the Learning Guide to bring to the student's attention a medical breakthrough in the prevention of Rh-factor complications.

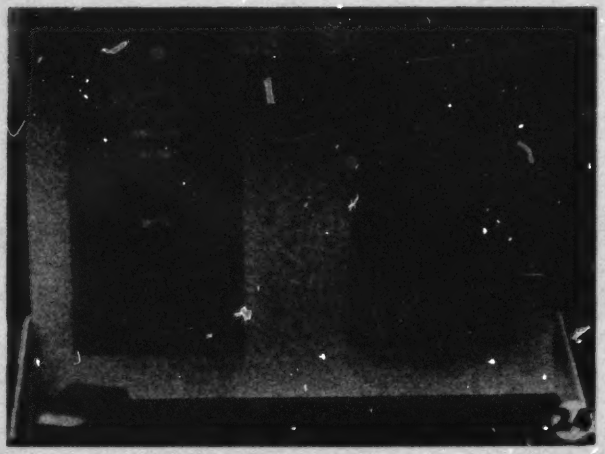
ABO blood group inheritance was treated with a series of seven programmed fill-in-the-blank statements included in the Learning Guide.

FIGURE 24. A directed observation of examples of incomplete dominance among plants and animals.

FIGURE 25. A directed observation of a model designed to show features which contrast dominant-recessive inheritance with incomplete dominance.

FIGURE 26. The study carrel for the unit, Genetic Counseling, showing the material used by the student during self-instruction.





RESISTANCE ARMEL

Because of the uniqueness of ABO blood type inheritance, it was possible to provide the student with two facts upon which the principle of blood type inheritance could be self-developed. Following the programmed instruction, the student was directed to apply the principle of blood type inheritance in the solution of a problem included in the Learning Guide. The problem was presented in a two part fill-in-the-blank format, the completion of the first part cueing the completion of the second part.

To complete the study of blood type inheritance, a comprehensive application problem was included in the instructional design. Set for the problem was established with the following audio presentation:

> Although the mechanism involved in blood typing is rather complex, the actual procedure for blood typing is simple. In unusual conditions, hospitals and courts have used the blood type inheritance as a basis for identifying parents of children. The evidence of blood typing does not absolutely prove kinship but it can be used as evidence to disprove kinship.

The student was then referred to the statement of a kinship problem:

> On a given day two male babies were released from the hospital. Upon arriving home, Mrs. G. noted that her baby had an arm bracelet marked "N." Mrs. N. insisted that she had her baby. The contest was settled in court on the basis of blood type analysis. Did Mrs. G. have her baby? Calculate your results . . .

Following the presentation of the problem, the student was directed to an instructional station (Figure 27). The purpose at the station was to gather blood typing data to be used in the solution of the problem. To avoid undue repetition of blood typing, the blood types of both maternal parents were included in the Learning Guide along with the statement of the problem. At the instructional station, the blood types of three of the remaining four parties, fathers and babies, were

given. A blood sample representing the blood type of the fourth party was provided for the student to type. Instructions for blood typing and a chart for interpreting the blood serum reactions were provided. By periodically changing the three given and the one unknown blood type, it was possible to maintain a fresh approach to the problem and to maintain the attending behavior of each student as the problem was encountered.

Once the blood typing exercise was completed, the student was instructed to pursue the solution to the problem. By calculating all of the possible inheritance combinations the student was able to discover that Mr. and Mrs. N. could have been the parents of either child but Mr. and Mrs. G. could be the parents of only one of the children. Thus, by a process of elimination, kinship between parents and children was established.

To aid the student in the solution of the problem, the answer, not the calculations, was included, upside-down, on the bottom of the Learning Guide page on which the problem appeared. If the student experienced excessive difficulty in solving the problem, the student was directed to a demonstration which displayed the entire solution (Figure 28). Closure for the instructional event was achieved through the audio medium by recalling the examination of several inherited traits such as eye color, tasting ability, and blood type. Also, considered in the closure was a reference to the application of trait expressions in the establishment of kinship identities.

The application of inheritance principles was extended by examining the mode of sex inheritance. Set for this instructional event

was established by relating some mystical explanations for the determination of an individual's sex. The student was then instructed to examine the supplementary materials, "How is Sex Determined?" (Appendix E). Direction for an attentive study of sex determination was provided using the audio medium. Three Learning Guide questions were designed in a fill-in-the-blank style to provide a summary of sex inheritance. A Learning Guide figure was added to provide a summary of the sex inheritance calculations.

As an addendum to the study of sex inheritance, the concept of probability was incorporated into the instructional sequence. The reasons for including probability at this point in the instructional system are: (1) the studies of dominant-recessive inheritance and incomplete dominance are complex in themselves; (2) the study of sex inheritance is straight forward and uncluttered; and (3) the student should have had sufficient practice with inheritance problems to be able to readily add the dimension of probability. The concept of probability was treated through the audio medium using coin flipping, drawing playing cards, and tossing dice as examples. To reinforce the audio tape presentation and provide a summary of the concept of probability, the student was instructed to complete a true and false question and a series of five fill-in-the-blank questions. The fill-in-the-blank questions were designed to be progressively more complex leading to the application of probability to the concept of sex inheritance.

Sex linked inheritance was developed as the final instructional event in the sequence of Human Applications. Set for the instructional event was established with the audio medium by citing some examples of sex linked traits. The instructional event evolved by referring the

student to examine Learning Guide figures which symbolically depicted sex linkage, contrasted the male and female expressions of sex linked traits. To assure a thorough study of the Learning Guide figures, the audio medium provided direction for the student. As a self-check, the student was directed to a Learning Guide problem solving question which was designed for the application of the principles of sex linkage. In a fill-in-the-blank format, the student was required to calculate the chances of normal boys, afflicted boys, normal girls, carrier girls, and afflicted girls if their mother was a carrier and the father was normal.

The pedigree of hemophilia among the decendents of Queen Victoria was included in the Learning Guide as an example of the transmission of a sex linked trait through several generations. The audio medium was utilized to direct the student in the examination of the pedigree. The primary function of the pedigree as an invaluable tool for genetic counseling was stressed. To confirm the value of a pedigree, the student was placed in the role of the genetic counselor and was required to respond to several Learning Guide questions which required an analysis of the pedigree and the application of the principles of inheritance. These Learning Guide questions were designed at the problem solving level and were prepared as multiple choice, true and false, and fill-in-the-blank formats.

The final instructional event involved a color vision test. The student was directed to examine a Color Blindness Test (Figure 29) for the purpose of identifying variations in color vision ability, for example, red-green or pastel-shade color blindness. With the completion of the color vision test, the student was instructed to calculate the

FIGURE 27. An investigative study of an inheritance problem involving the identification of kinship through blood typing.

FIGURE 28. The solution to an inheritance problem involving the identification of kinship through blood typing.

FIGURE 29. A colorblindness test display enabling the student to determine his color vision ability phenotype.

solution to a Learning Guide problem solving question. The problem required the student to predict the number of normal sighted children from a normal sighted parent and a parent with color vision ability like that of the student.

Closure for the instructional event was achieved with the audio medium by recalling the mode of sex inheritance, the study of some sex linked traits, and the concept of probability.

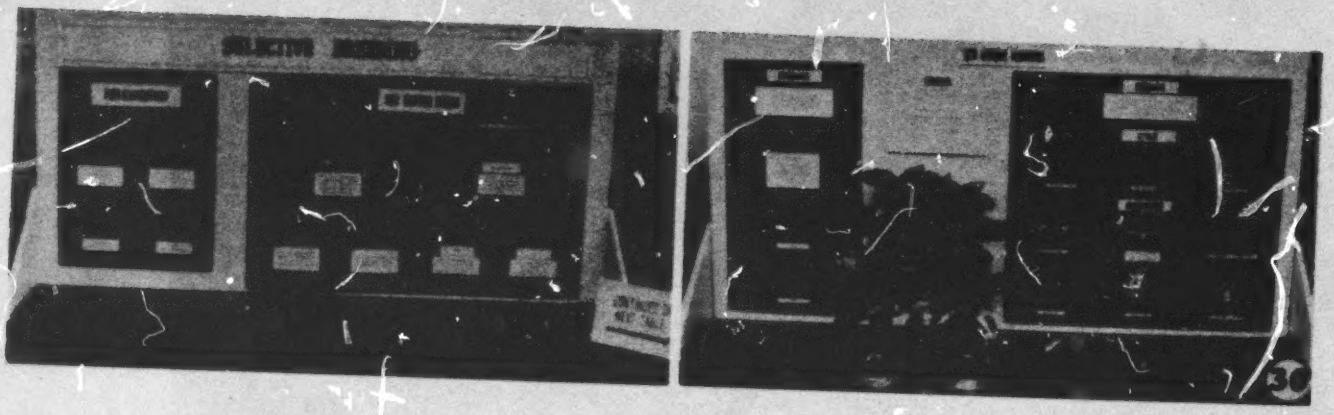
The last instructional system, Selective Breeding, was included in the unit to illustrate economic applications of man's knowledge of heredity. Set was established using the audio medium by identifying examples of selective breeding.

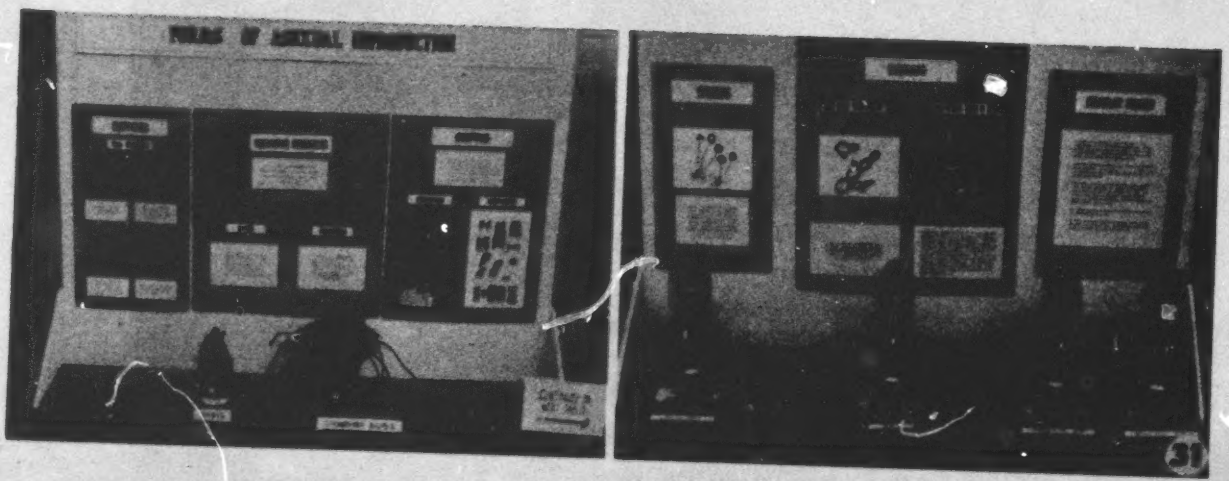
The first instructional sequence, Sexual Modes, was developed by instructing the student to observe a photo demonstration, Selective Breeding (Figure 30). The demonstration illustrated the varieties of economically valuable organisms, plants and animals, developed through the careful selection of parents. The instructional sequence was completed with two Learning Guide questions summarizing a definition and identifying examples as well as advantages of selective breeding.

Set for the last instructional sequence, Asexual Modes, was established using the audio medium to identify shortcomings of the sexual mode of selective breeding. In contrast, the advantages of the asexual mode of selective breeding were developed by instructing the student to observe the demonstration, Forms of Asexual Reproduction (Figure 31). The student was pre-cued to complete a Learning Guide table which was designed to summarize the forms of asexual reproduction, examples, and advantages. Information for the completion of the Learning Guide table

FIGURE 30. A photo and microscope study display, caption directed, which demonstrates examples of economic benefits derived through selective breeding of organisms.

FIGURE 31. A caption directed display of photos, sketches, and living specimens depicting forms of asexual reproduction.





as well as direction for the observation were provided with brief captions included with the demonstration.

Closure for the instructional unit was achieved using the audio medium. The closure was designed to reflect upon man's accomplishments "armed with the knowledge of genetics" and to predict man's future accomplishments.

Didactor Programs

Didactor programs (Appendix F) were designed to supplement the instruction of selected unit areas. For each of the selected areas, the Didactor program replaced the audio tape presentation so that the student using the Didactor would receive the same information that was presented on the audio tape. The only difference between a student progressing through the instructional material with only the audio tape presentation and a student progressing through the instructional material with the audio tape presentation supplemented by the Didactor would be the media of presentation. The decision to supplement a particular unit area was based upon the difficulty of the subject matter. For the unit, Birth, the areas which were chosen for programmed instruction included fertilization through neurulation, drugs and development, and diffusion and osmosis. The instructional material, fertilization through neurulation was divided into two program sections, fertilization to implantation and neurulation. The menstrual cycle from the unit, Birth Control, was another instructional area designed for programming. The last instructional areas specified for supplementation were included in the unit, Genetic Counseling. The specified areas were dominant-recessive inheritance, incomplete dominance, sex determination and sex linkage. The

instructional area, dominant-recessive inheritance, was treated in two program segments: dominant-recessive inheritance principles and calculations of inheritance problems.

The development of each Didactor program was begun by organizing the subject matter content into an outline format. The goals underlying the outline were the already established unit goals. The outline was developed to serve as a guide for the logical development of the program mainstream and as a guide for the structure and sequence of frames.

Intrinsic programming was the style used in the development of the Didactor programs. The basic technique of the intrinsic program was to present a relatively large quantity of information (25 to 100 words per frame) followed by a question which would permit the student to demonstrate his achievement. Correct responses were reinforced in two ways. The first and most frequently used form of reinforcement was to offer a single word of affirmation as the initial word of the subsequent frame, for example, "O.K." or "FINE." The positive affirmation was usually not a superlative word or phrase because prior to any given frame, the student may have been making errors and an affirmation such as "Very Good" would not be appropriate. The alternate method of reinforcement was to inform the student his response was correct, usually with an "O.K." and then elaborate upon the logic underlying the correct response. For example,

> O.K. Though the menstrual cycle involves the pituitary gland, ovary, and uterus, it is the hormone secretions of the pituitary gland, Follicle Stimulating Hormone (FSH), as well as the secretions of the ovary, estrogen and progesterone, which are responsible for the events of the menstrual cycle.

Incorrect responses were followed by a reprimand, "No," and an

explanation redirecting the student's logic which resulted in the incorrect answer. For example,

> No. The answer to the previous question is 14 days because the number of days between the day of ovulation, the 14th day, and the last day of a 28 day cycle is 28-14=14.

In the development of each Didactor program or program section, the mainstream frames were written first. The major concern underlying the writing of a frame was to be concise. The number of words (typewriter characters) that could be carried on a frame were limited. The student's time involvement was important. Illustrations were frequently used to enable a compact presentation. Additional concerns in the development of each program included being creative and innovative in style, using a conversational approach whenever possible, anticipating student misconceptions, writing significant questions, and finding logical wrong answers for questions designed to check the progress of the student. After the mainstream frames were written, the corrective frames were desinged and the program strategies were finalized. The author found it difficult to write corrective frames simultaneously with the writing of mainstream frames. It was difficult to keep the total flow of the program in mind with the periodic interruptions required for the writing of a corrective frame.

The most commonly employed strategies were to either provide correction for an error and have the student continue in the mainstream or have the student repeat the frame after correction for the error was provided. A variation of the latter strategy was to have the student go back two or more frames if it was felt that the error was indicative of an earlier misunderstanding. For example in the Didactor program,

Genetic Counseling, an incorrect response to the question of frame five would receive correction in frame six. Following the correction of frame six, the student was returned to frame four where the basic principle of the concept was established. The student would have to repeat frame five as well. Another variation of frame repetition would occur if the incorrect choice could be interpreted either as a careless error or an error founded in a lack of understanding. The student would be given an opportunity to select from alternatives, go on, try the last frame again, or go back to the frame initiating the concept. An example from the unit, Birth, is:

> No. You missed the question. Can you figure out why? If you would like to try the question again, Press A. If you inadvertently selected the wrong choice and would like to go on, Press B. If you are experiencing difficulty in visualizing the events in the process of neurulation, it is desirable for you to review the process from the beginning. Press C.

A third variation requiring frame repetition would come about if it was thought that the error resulted from a lack of attending behavior. One example from the program, Birth is:

> Oh, come on. Get with it. If red stem color is the dominant expression of a trait because it overrides or "suppresses" the alternate expression, then the alternate expression cannot be called dominant. Now, try again.

In some cases, the nature of the question and the foils necessitated a specifically correlated correction. Thus a corrective frame would be written to correspond with each incorrect choice. In other cases, a single corrective frame was used for any of the incorrect choices. The decision to use the former or latter alternatives was based upon the attempt to provide the most meaningful correction. For example, in the program, Genetic Counseling, the selection of one question

foil indicated an incomplete understanding; whereas, the selection of the alternate foil indicated complete misunderstanding. Appropriately, two specifically correlated corrective frames were designed. In another section of the Genetic Counseling program, the question presented was not designed to differentiate degrees of understanding. The selection of either foil would indicate a lack of understanding. Consequently, one corrective frame was designed to compensate the misconception.

Other strategies employed in the design of the Didactor programs were chaining, options for practice, paced learning, and mastery. Chaining was a technique which was utilized when several frames, two or more frames, were required for the presentation of an increment of information. Chaining was also used to construct a complex concept by a series of additive increments of information. For example, the program section, Diffusion - Osmosis of the unit, Birth, was initiated with definitions of diffusion and osmosis. The next frame required the student to identify an illustrated situation as either osmosis or diffusion. The following frame required the student to select from three illustrations the one which exemplified the most rapid diffusion rate. In the subsequent frame, the student was required to identify the direction of diffusion. Eventually the program section ended with an application of the definition, the rate, and the direction of diffusion.

A technique developed in the program, Genetic Counseling, was to end each instructional section with a frame indicating to the student that the program was successfully completed and that an option was available, to review, to go on, or to put to practice the principles just studied. The optional practice series was designed to progress from

levels of lower cognitive ability to more complex levels. The initial frames of a practice series presented knowledge level questions. Subsequent frames presented comprehension and application questions.

Paced learning was a technique which was employed to build skill or encourage attending behavior. This technique was used in the development of a practice series in the unit, Genetic Counseling, and in the Diffusion - Osmosis program section of the unit, Birth. Increments of information were presented for a limited time, such as ten seconds or for twenty seconds. If a response was made within the time limit the student would be advanced in the mainstream or to corrective information depending upon the response. If the time limit expired before the student responded, corrective information would be automatically presented.

Mastery was a technique used in the menstrual cycle program of the unit, Birth Control. Feedback from evaluation studies indicated that the general studies male student did not perform as well as the female student on test items pertaining to the evaluation of the menstrual cycle study. To compensate for this apparent deficiency, the menstrual cycle program was divided into three sections. The first and last sections, eight and four frames, respectively, were selected for mastery because of their complexity. If the student made an error during either the first eight frame section or the last four frame section, the memory system of the Didactor would be activated. With the completion of the section in which the error occurred, the student would be informed that an error was made, that mastery was essential, and that the section would have to be repeated.

After the Didactor programs were written, each frame was typewritten on a four inch by six inch white card. A flow chart (Appendix F) was formulated which designated the mainstream, corrective frames, and the various strategies. The typewritten cards and the flow chart were submitted to the Didactics Corporation, Mansfield, Ohio, for coding and filming. Instructions for preparing and coding the Didactor programs are available in a Didactics Corporation handbook, "How to Make and Code Your Own Programs for the Didactor System - A System of Teaching Tools."

Method of Evaluation

Four evaluation instruments, one pretest and three unit tests (Appendix G) were used in this study. The tests were designed to assess student achievement and strategy effectiveness for each instructional unit. The three unit tests were each composed of 15 test items; the pretest of 45 test items was a compilation of the three units tests.

The instruments were developed by pooling questions from evaluation items which were previously used to appraise the prototype materials after they were introduced into the regular general studies biology course. For each of the 15 behavioral objectives identified as unit goals for student achievement, test questions were selected on the basis of test item congruence and validity. A three member panel of experts judged the test items on the basis of congruence. The minimum acceptable validity value was established at 0.25. Each instrument item was of multiple choice format having one correct answer mixed with

four foils. The test questions were designed according to the recommendations of Sanders (1966) and Lombard (1965). Lastly, with the assistance of a tests and measurements expert, the test items were classified according to Bloom et al. (1971).

Three student groups were selected to be involved in the study, a pretest group, a control group, and an experimental group. The purpose of the pretest group was to establish a standard of student entering competency. The role of the control group was threefold: enable the determination of net achievement, permit the assessment of instructional strategy effectiveness, and serve as a standard for comparing the achievement of the experimental group. The function of the experimental group was to permit the evaluation of Didactor effectiveness.

The 45 item was administered to the pretest group at the onset of the course; the control group participated in the regular instructional program; and the experimental group participated in the regular instructional program supplemented with the Didactor materials. The control and experimental groups were given identical weekly achievement tests. Also, on a weekly basis, the control and experimental groups completed a student evaluation instrument (Appendix H) rating various aspects of the unit such as relevance, interest level, experiments, etc. The experimental group completed a student evaluation which provided for rating various aspects of the Didactor such as difficulty of the programs and assessing the value of the material.

Three sections of students were chosen to compose the pretest group and four sections were chosen to compose the pretest group and

four sections were chosen to compose the respective control and experimental groups. Each section included approximately 24 students

The criterion for selecting student sections was class meeting time. Sections were chosen to enable the students in the control and experimental groups to attend the Learning Center on the first and second days of self-instruction period. By attending the Learning Center on the first or second days of self-instruction, it was possible to administer the evaluation instruments during the same week that self-instruction was completed. A second reason for selecting student sections on the basis of class meeting time was the number of Didactors which were available. The six Didactors used in this study could adequately serve 48 students during each self-instruction day.

A test item analysis was completed to determine the validity of each question used in the weekly achievement test. Kuder-Richardson Formula 20 analysis was carried out to determine the reliability coefficient of each weekly achievement test. An analysis of item difficulty was used as the measure to assess the effectiveness of the instructional strategies.

Analysis of covariance of pretest scores and weekly achievement test scores of the control group was used to determine the net student achievement. Similarly, analysis of covariance of control group and experimental group achievement test scores was used to assess the supplementary effectiveness of the Didactor. In this analysis, only the items which were Didactor taught composed the test score. In each analysis of covariance, total SAT Verbal and SAT Mathematics scores were used as the covariate.

Lastly, the student evaluation instruments were analyzed. Student responses for each item in the instruments were tabulated and ratings were translated into percentage figures.

CHAPTER IV

RESEARCH FINDINGS AND DISCUSSION

Results of the evaluation instrument analysis, shown in Table IV, indicate favorable test reliability (Thorndike and Hagen, 1969) and compare satisfactorily with test construction validity standards established by Ebel (1954): 14 per cent of the items under 0.2; 42 per cent, between 0.2 and 0.4; and 44 per cent, above 0.4.

TABLE IV

Achievement Test Item Analysis

Unit	Reliability Coefficient Kuder-Richardson Formula 20	Range of Item Validity		
		0.2	0.2 - 0.4	0.4
Birth	0.47	2	8	5
Birth Control	0.45	2	8	5
Genetic Counseling	0.73	2	3	10

Table V provides a summary of the components involved in the assessment of effectiveness of various instructional strategies. The essential components are: (1) the strategy classification; (2) the cognitive level of student achievement; (3) the number of test items used to determine the effectiveness of a strategy at a particular cognitive level; (4) the validity range of the evaluation items; and (5)

the average student behavioral objective achievement. The strategy classification is based upon the significant medium used in the instructional sequence to effect a cognitive or psychomotor behavioral

TABLE V

Strategy Effectiveness

	Strategy	Cognitive Level	Number of Items	Validity Range	Average Student Achievement (%)
	Guided Discovery	Comprehension	3	.28 - .38	54
		Application	1	.61	42
DIRECTED OBSERVATIONS	Learning Guide Visuals	Knowledge	6	.14 - .53	78
	Learning Guide Tables	Knowledge	1	.32	83
		Application	2	.51 - .54	47
	Photos	Knowledge	6	.04 - .55	84
		Comprehension	2	.38 - .40	92
	Sketches	Knowledge	1	.07	86
		Comprehension	1	.46	63
	Models	Comprehension	2	.26 - .56	87
	Preserved and Living Specimens	Knowledge	2	.20 - .36	76
		Comprehension	1	.20	89
	Investigations	Application	3	.44 - .63	76
	Simulations	Knowledge	2	.02 - .16	92
		Application	1	.43	50
	Film Clip	Knowledge	1	.31	92
	35 mm Slides	*			
	Supplementary Readings	Application	2	.48 - .69	76
	Study Carrel Visuals	Knowledge	3	.07 - .63	84
		Comprehension	1	.51	62
	Programmed Instruction	Knowledge	1	.38	88
		Comprehension	2	.47 - .59	79
	Learning Guide Problem Solving and Application Questions	Knowledge	1	.33	74

* Psychomotor skill, a survey of 158 students revealed 90 per cent were successful in performing the activity.

change. The taxonomic category of student achievement is represented by the knowledge, comprehension, and application cognitive levels. The number of test items used to assess student achievement mediated by each strategy is variable. The number of test items for a particular strategy classification and cognitive level reflects the number of times the strategy was used in the three units. The validity ranges for the test items are the coefficients determined through post achievement test item analysis. As pooled for assembly into the three unit achievement tests, the minimum acceptable test question validity coefficient was 0.25. Test items were pooled from 40 item evaluation instruments. These tests had been previously administered at the conclusion of each of the three units. Average student achievement reported represents the mean test item analysis difficulty coefficient for the test items.

Average achievement for the knowledge level of cognitive ranged from 74 per cent to 92 per cent; for the comprehension level, 54 per cent to 92 per cent; and for the application level, 42 per cent to 76 per cent. Several strategies employed in this research study were effective in facilitating learning at the knowledge and comprehension levels with the most effective strategies being: programmed instruction; study carrel visuals; and directed observations of Learning Guide tables, simulations, models, sketches, and photos. Investigations and supplementary readings were effective methods mediating mastery at the application level.

Table VI reveals the student ratings of the unit self-instruction tapes, study carrel and demonstration table experiments and observations, and the usefulness of the supplementary readings. Mean ratings for the three instructional units disclose that 63 per cent of the students

TABLE VI

Student Evaluation of the
Effectiveness of Audio Tapes, Experiments and
Observations, and Supplementary Readings

Unit	Characteristic	Per cent Rating				
		Very High	High	Moderate	Low	Very Low
Birth	Self-instruction tapes in the study carrel as aids to the understanding of the material	28	44	28		
	Experiments and observations in the study carrel as aids for understanding the material	25	59	16		
	Experiments and observations at demonstration tables as aids for understanding the material	19	48	33		
	Usefulness of the supplementary readings provided in the study carrel	13	36	42	9	
Birth Control	Self-instruction tapes in the study carrel as aids to the understanding of the material	17	48	32	3	
	Experiments and observations in the study carrel as aids for understanding the material	5	34	57	4	
	Experiments and observations at demonstration tables as aids for understanding the material	8	35	57		
	Usefulness of the supplementary readings provided in the study carrel	9	28	52	11	
Genetic Counseling	Self-instruction tapes in the study carrel as aids to the understanding of the material	9	41	43	7	
	Experiments and observations in the study carrel as aids for understanding the material	14	33	46	7	
	Experiments and observations at demonstration tables as aids for understanding the material	14	45	38	3	
	Usefulness of the supplementary readings provided in the study carrel	18	44	34	4	

assigned the self-instruction tapes a very high or high rating; 57 per cent, ranked the experiments and observations as very high or high; and 49 per cent, considered the usefulness of the supplementary readings to be very high or high.

The ratings of Learning Guide objectives are recorded in Table VII. Considering usefulness, the objectives received very high and high ratings by a convincing majority of students. Average ratings for the three instructional units regarding usefulness in self-instruction

TABLE VII

Student Rating of Learning Guide Objectives

Unit	Usefulness	Per cent Rating				
		Very High	High	Moderate	Low	Very Low
Birth	Self-instruction	28	43	28	1	
	Test Preparation	39	33	27	1	
Birth Control	Self-instruction	23	46	28	3	
	Test Preparation	25	46	28	1	
Genetic Counseling	Self-instruction	11	59	29	1	
	Test Preparation	13	54	30	3	

indicate that 68 per cent of the students regarded the objectives very high or high and regarding usefulness in test preparation, 70 per cent of the students judged the objectives very high or high.

Learning Guide ratings for usefulness are reported in Table VIII. The Learning Guide was declared useful in self-instruction and in test preparation by a considerable majority of students. Mean ratings for the three instructional units regarding usefulness in self-instruction reveal that 81 per cent of the students considered the Learning Guide very high or high; and, regarding usefulness in test preparation, 77 per

TABLE VIII

Student Rating of the Learning Guide

Unit	Usefulness	Per cent Rating				
		Very High	High	Moderate	Low	Very Low
Birth	Self-instruction	37	46	16	1	
	Test Preparation	46	33	20	1	
Birth Control	Self-instruction	39	43	18		
	Test Preparation	42	35	23		
Genetic Counseling	Self-instruction	20	57	21	2	
	Test Preparation	20	54	26		

cent of the students acknowledged the Learning Guide very high or high.

The data shown in Table IX denote significant control group achievement for each of the instructional units, Birth, Birth Control,

TABLE IX

Analysis of Covariance for Pretest and Control Groups on Unit Achievement (Covariate: Total SATV and SATM)

UNIT	Source of Variance	df	SS	MS	F
Birth	Between Groups	1	1229.05	1229.05	309.939*
	Within Groups	131	519.48	3.97	
	Total	132	1748.53		
Birth Control	Between Groups	1	1297.41	1297.41	361.795*
	Within Groups	132	473.36	3.59	
	Total	133	1760.77		
Genetic Counseling	Between Groups	1	733.39	733.39	146.823*
	Within Groups	123	614.39	5.00	
	Total	124	1347.78		

*significance coefficient at 0.001 level = 10.83

and Genetic Counseling, respectively. Table X represents the adjusted mean scores of the pretest and control groups. Average net gains of 41 per cent, 42 per cent, and 33 per cent were realized by the control group for Birth, Birth Control, and Genetic Counseling, respectively.

Relevance, practical value, and interest level received high

TABLE X

Net Student Achievement Comparing Unit Test Scores for Pretest and Control Groups

Unit	Pretest		Control	
	Number of Students	Adjusted Mean	Number of Students	Adjusted Mean
Birth	70	5.47	64	11.51
Birth Control	70	5.69	65	11.94
Genetic Counseling	70	5.85	56	10.74

TABLE XI

Student Ratings of Relevance, Practical Value, and Interest

Unit	Number of Students	Characteristic	Per cent Rating				
			Very High	High	Moderate	Low	Very Low
Birth	64	Relevance	52	46	2		
		Practical Value	44	50	6		
		Interest	48	39	13		
Birth Control	65	Relevance	46	49	5		
		Practical Value	51	43	6		
		Interest	34	52	14		
Genetic Counseling	56	Relevance	23	57	20		
		Practical Value	18	57	25		
		Interest	18	46	34	2	

ratings for each instructional unit by a decisive majority of students. The results of the student questionnaire appraisal are shown in Table XI. One of the combined ratings, very high and high, was as large as 98 per cent. Several of the combined ratings, very high and high, were either 95 or 94 per cent. The lowest combined rating, very high and high, was 64 per cent.

Analysis of covariance of control and experimental (Didactor-taught) group scores indicates significantly greater experimental group achievement for the Birth Control and Genetic Counseling units.

TABLE XII

Analysis of Covariance for Control and Experimental Groups on Unit Achievement (Covariate: Total SATV and SATM)

UNIT	Source of Variance	df	SS	MS	F
Birth	Between Groups	1	0.69	0.69	0.312
	Within Groups	111	244.57	2.20	
	Total	112	245.26		
Birth Control	Between Groups	1	3.87	3.87	5.212*
	Within Groups	113	83.88	0.74	
	Total	114	87.75		
Genetic Counseling	Between Groups	1	13.28	13.28	7.192+
	Within Groups	91	168.05	1.85	
	Total	92	181.33		

* significance coefficient at 0.025 = 5.14
+ signicicance coefficient at 0.01 = 6.64

Although the experimental group achievement was not significantly higher than the control group for the unit Birth, adjusted mean scores shown in Table XIII reveal that the experimental group did better in average achievement. Both groups, control and experimental, spent an equivalent amount of time in self-instruction. Achievement gains shown by the experimental group are attributed to the teaching effectiveness of the Didactor and Didactor programs.

TABLE XIII

Net Student Achievement Comparing Didactor-Taught Objectives for Control and Experimental Groups

Unit	Control		Experimental	
	Number of Students	Adjusted Mean	Number of Students	Adjusted Mean
Birth	64	6.48	50	6.64
Birth Control	65	2.85	51	3.23
Genetic Counseling	56	5.64	38	6.42

The teaching effectivenss of the Didactor is shown in Table XIV. The average student achievement at the knowledge level of cognition is 87 per cent; at the comprehension level, 76 per cent; and at the application level, 75 per cent.

The student ratings reported in Table XV indicate that slightly more than 20 per cent of the students encountered more than moderate program difficulty. Similarly, only about five per cent of the students encountered more than a moderate amount of difficulty in operating the Didactor. Table XV also reveals that a high percentage of students

TABLE XIV

Cognitive Level Didactor Teaching Effectiveness

Unit	Objective Cognitive Level	Test Item Validity	Student Achievement (%)
Birth	Knowledge	.60	90
		.53	96
		.32	78
		.46	54
	Comprehension	.26	98
		.33	98
		.38	52
	Application	.28	58
		.43	64
Birth Control	Knowledge	.34	92
		.45	69
		.25	67
		.20	96
Genetic Counseling	Comprehension	.20	95
		.56	84
		.54	92
	Application	.63	82
		.44	92
		.69	87
		.54	71
		.51	40

TABLE XV

Student Rating of the Didactor and Didactor Programs

Unit	Characteristic	Per cent Rating				
		Very High	High	Moderate	Low	Very Low
Birth	Program difficulty		10	40	34	16
	Level of difficulty encountered in operating the Didactor		8	18	38	36
	Effectiveness of the program as an aid to understanding the material	28	62	10		
	Correlation of the program with the self-instruction material	44	52	4		
Birth Control	Program difficulty	2	16	37	19	26
	Level of difficulty encountered in operating the Didactor	2	2	6	19	71
	Effectiveness of the program as an aid to understanding the material	18	59	19	4	
	Correlation of the program with the self-instruction material	31	55	14		
Genetic Counseling	Program difficulty		40	40	20	
	Level of difficulty encountered in operating the Didactor		3	8	30	59
	Effectiveness of the program as an aid to understanding the material	18	50	29	3	
	Correlation of the program with the self-instruction material	34	55	11		

considered the Didactor programs to have a high correlation with the self-instruction material and to be highly effective as aids in understanding the instructional materials.

TABLE XVI

Student Rating of the Didactor and Didactor Programs as an Assurance of Correctly Answering Learning Guide Questions

Assurance	Per cent Rating for the Units		
	Birth	Birth Control	Genetic Counseling
Yes	98	90	82
No	2	10	18

Consideration of the student appraisal of the Didactor and the Didactor programs shown in Table XVI indicates that a substantial majority of students considered that the Didactor and the Didactor programs provided assurance of accurate self-instruction progress.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The goal of this research study was to structure learning experiences which would systematically lead students from that which was within their grasp to higher levels of understanding and behavior. In formulating learning experiences, a systems approach was applied. The dimensions of the systems approach included: (1) conduct of a needs assessment; (2) identification of goals set in terms of performance criteria; (3) design of learning materials using a variety of strategies and media; (4) revision of the learning materials made on the basis of evaluation and questionnaire feedback; and (5) determination of student achievement by comparing pretest and post test scores. In addition to the basic goal of the research study, Didactor programs were designed to supplement selected portions of the instructional materials. The effectiveness of the Didactor and Didactor programs were determined using achievement tests and student questionnaire appraisals.

As a result of the needs assessment, student interviews and the expertise of instructional staff, three subject matter areas titled Birth, Birth Control, and Genetic Counseling were selected as topics for this research study. Subordinate topics based upon biological principles were selected for each unit. In turn, each of the subordinate topics was subdivided to cover more explicit and definitive categories. Based upon the content areas to be considered in the three

instructional units, student behavioral objectives were written. Finally, instructional systems were designed to enable students to accomplish the predetermined objectives.

Prototype materials were developed and a pilot study was conducted with six volunteer students. Test results and feedback from the pilot study were analyzed and where necessary strategies were modified, replaced, or discarded to augment the overall effectiveness of the instructional system. After being introduced into the regular general studies biology format, analysis of student feedback, questionnaire appraisal, and comprehensive testing led to the final revisions of the instructional system.

Audio-tutorial instruction served as the basic mode into which systems for individualized instruction using technological resources were implemented. An array of visual displays, investigatory exercises, and supplementary readings were included to add breadth to the guided discovery design. Whenever necessary, original visuals and investigatory exercises were developed and implemented.

A Learning Guide for each instructional unit was designed to establish the setting, specify learning goals, direct system interactions, and provide a concise review of the material of each instructional unit. To achieve the desired student interactions, a variety of question forms were incorporated to elicit student response. Each question type was specially incorporated to reinforce and summarize a particular activity. A programmed instruction format was incorporated in the Learning Guide for the treatment of various involved concepts. Summative tables and figures as well as specially designed illustrations were also utilized.

The evaluation instrument used to determine student achievement and strategy effectiveness was developed by pooling questions from pilot study evaluation items. Test questions were selected on the basis of congruence with behavioral objectives and validity coefficients. Lastly, the questions were classified according to the taxonomic cognitive level which they evaluated. The taxonomic classification of questions enabled the estimation of strategy effectiveness at various levels of cognition.

Didactor programs in a branched format were developed to teach complex areas of the instructional materials. Various programming strategies were used to advance the learner through the subject matter as well as monitor his progress.

Conclusions

A systems approach is an invaluable methodology for instructional accountability. It is a tool that is applicable to the management of the learning process. A systems approach provides the format for the assessment of learning needs, for the design of strategies to accommodate the needs, for the evaluation of the strategies, and for the measurement of achievement facilitated by the strategies. A systems approach is an instrument whereby learning theory can be established relative to the elements of input and the effected output.

Learning can be facilitated as well or better through the employment of technological resources than through traditional group-paced teacher-directed classroom activities. Technology is an important means of transferring knowledge and as a means of knowledge transfer, technology has several advantages over the in-person teacher. From hour to hour, day to day, an instructional unit can be presented with absolute

reproducability. A student can become repeatedly involved in an instructional sequence. Large numbers of students can be individually and uniformly involved in an unvarying instructional process. The student can experience instruction through one or all of the senses, individually, or simultaneously.

The need for direct teacher contact appears to be necessary only when the student experiences learning difficulty. The student learns independently in a self-paced individualized instruction system which provides for attention when it is required. A teacher's comments, confirmation, correction, and encouragement, coupled with a strategically designed instructional system provide that combination of factors resulting in a meaningful environment for learning. The quality of student-teacher contact in the learning environment appears to be more significant than the quantity of that contact.

Cognitive achievement in the audio-tutorial mode can be realized through the employment of several instructional strategies. Knowledge and comprehension levels of cognition are facilitated with the directed observation of tangible entities such as photos, sketches, models, and filmclips. The cognitive level of application can only be achieved if the learner is involved in application experiences. Investigative activities and case studies are meaningful strategies effecting the application ability. Psychomotor learning can be accomplished through narrated visual media which emphasize significant steps of the skill.

A major shortcoming of audio-tutorial instruction is that learner certitude of accurate progress is not available. Audio-tutorial programs

tend to be set in a format which periodically requires the learner to respond to questions in a self-instruction manual. However, as the learner responds, he has little assurance that his response is adequate. The needed assurance and confidence of successful progress in a self-instruction system must be provided, preferably in the style and design of a learning guide.

A learning guide, developed as an instructional companion for the learner, is both significant as an instructional aid and as a learning agent. The purpose of a meaningful learning guide is to elicit student interaction and to stimulate attending behavior. Lastly, a learning guide should effect learner confidence; it should provide assurance to the learner that his progress in a self-instruction effort is accurate.

The application of rhetoric guidelines and technical teaching skills such as establishing set and closure to the design of the audio-tape presentation of self-instruction systems is essential. Audio-tape presentation deserves more attention in planning and organization than the usual classroom teaching presentation. The designer of an audio tape presentation must put forth more effort in developing the audio-tutorial narrative than in styling a typical oral teacher presentation. The designer must realize that once an audio presentation is committed to the recorder tape, the student can only replay the recording; the student does not have the opportunity for student-teacher communication, the teacher no longer has the facility of rephrasing a statement as frequently occurs when student facial expressions in a classroom indicate a lack of discernment. The audio tape presentation is an integral component of the learning environment. It should do more than serve as

a means of task direction; it should serve to facilitate learning. Because the audio-tutorial tape serves as the backbone for most self-instruction systems, the total effect of the self-instruction system cannot be more significant than the message of the supportive medium.

Student behavioral objectives add considerably to the embodiment of the learning environment. The construction of specific student objectives in a behavioral framework facilitates learning. Student behavioral objectives are pre-cueing devices which effectively facilitate learning and they dictate direction for the design of instructional strategies and systems. The student is handicapped in his learning endeavor without the aid of behavioral objectives. The instructional system designer is left aimless without the guidelines of direction, behavioral objectives.

The gains derived from a needs assessment mandate its application in the development of any worthwhile instructional enterprise. The needs assessment not only provides the instructional designer with the clues upon which to establish objectives that encompass student concerns and subject content. Needs assessment also provides a temperament for styling the instructional systems. Consequently, a needs assessment is essential if the instructional system is to be relevant, valuable, and interesting to the student.

The Didactor is a teaching instrument that can significantly enhance learning because it has the capability of placing the student in a meaningful and effective learning environment. An explanation for the enhanced learning mediated with the Didactor is that the Didactor provides corrective explanations for student errors as the student

understandings are periodically monitored. Although a student may replay an audio tape presentation, repetition does not insure clarification; the student is not provided with additional explanations from different frames of reference.

The Didactor is an efficient agent in teaching problem solving. Skillful problem solving ability requires the recollection and the understanding of facts and/or rules as well as their application. Evidence indicates that the Didactor has the capability of facilitating high learning achievement at the knowledge, comprehensive, and application levels which are essentials of problem solving cognition.

Recommendations

Several avenues of continued research have been opened as a result of this research study. Such research should lead to the development of more scientifically and more efficiently designed learning systems. The author recommends that each strategy used in this research study be analyzed for its specific contribution to the total learning process. Various strategies should be substituted and interchanged to permit comparative strategy effectiveness to be determined. This would serve as a means of identifying the most efficient and effective instructional means. Also, strategies should be identified which effect higher levels of cognition, analysis, synthesis, and evaluation.

Another recommendation is to correlate specific strategies with specific types of learning. For example, a study might be designed to determine characteristics in a strategy which make the strategy effective in concept learning. In addition to their usual use, it might be

found that programmed instruction or audio tape presentations are adequate and feasible methods in achieving concept realizations.

Other studies should involve the development of instructional systems which offer the student remedial or advanced instruction. For example, in a Genetic Counseling unit, students may require additional help in dealing with the mathematics of fractions or in a unit on Birth, a student might want to more intensely pursue the ramifications of in vitro development. The development of various remedial and enrichment instructional modules could be highly beneficial to the student.

The areas of greatest usefulness of the Didactor should be explored. The instrument has tremendous potential as an instructional agent. Programming strategies should be investigated and documented for their effectiveness in aiding learning at various levels.

Better methods for the evaluation of student achievement should be developed. A dilemma exists in the attempt to design valid and reliable test instruments which indicate high student achievement. Test item analysis formulae are based upon norms which tend to penalize short tests as well as penalize test items to which most students correctly respond.

Another recommendation is that a study be conducted to determine the extent of the contribution which the Learning Guide makes to the learning process. A comparative study whould be conducted with two groups of students. One group of students should use the Learning Guide that was developed for this study and the second group should use a learning guide of more traditional design, entirely composed of questions requiring several word responses. The two groups would then be compared in terms of their achievement on unit tests.

The last recommendation is that the educational profession adopt the systems approach as an invaluable tool which can be used in the development of efficient and effective learning materials.

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